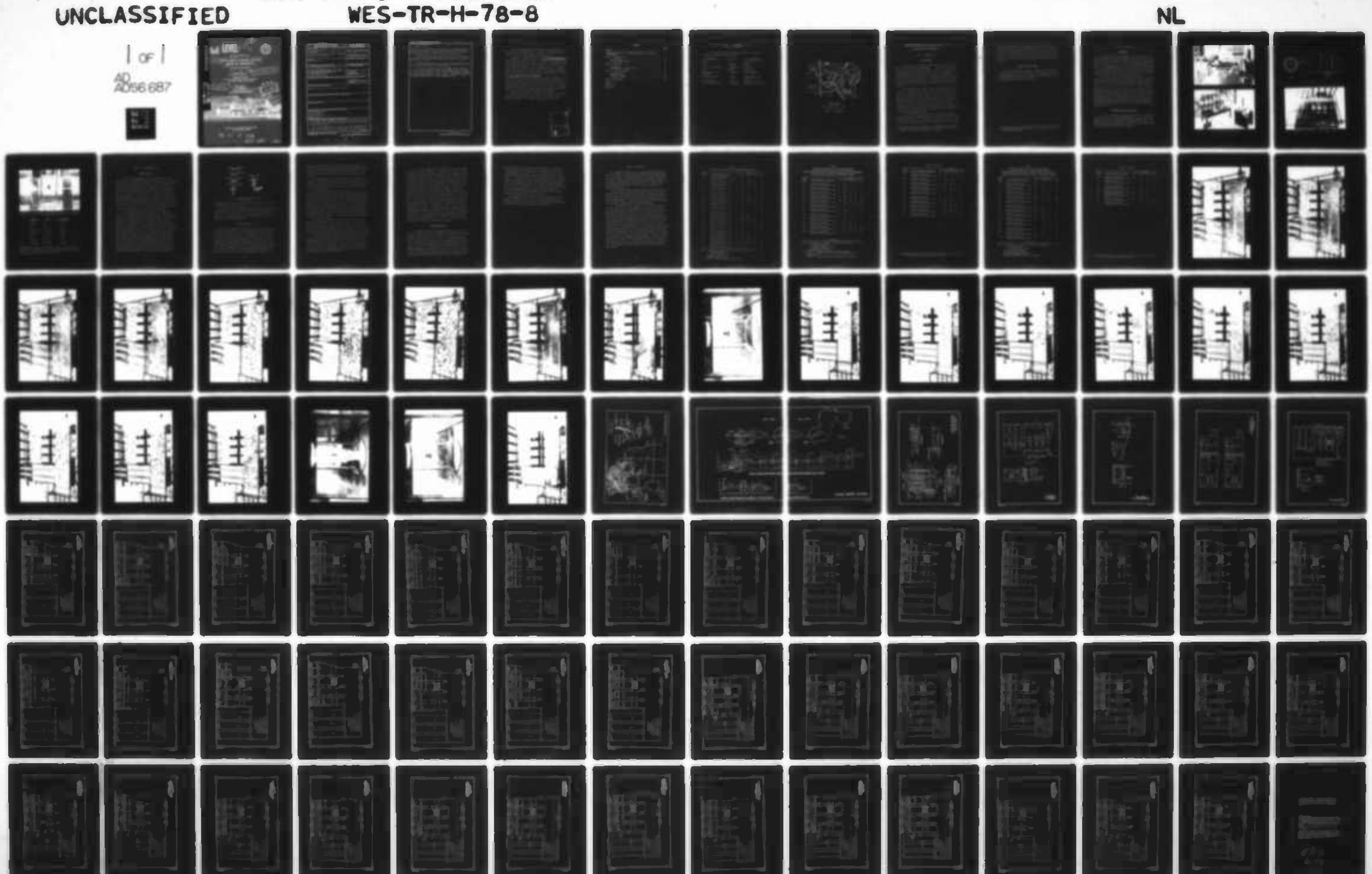
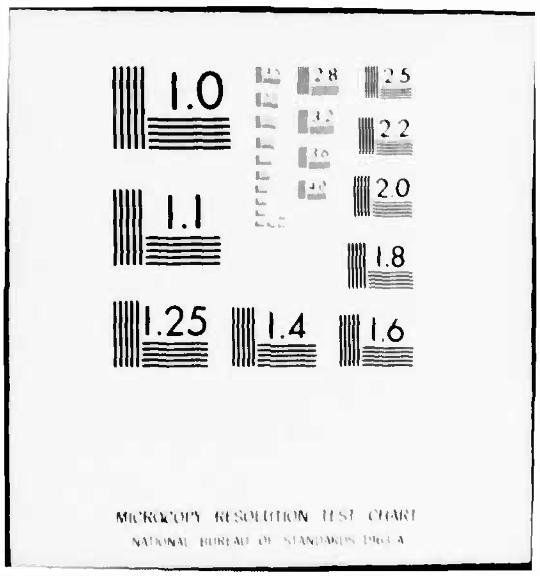
AD-A056 687 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 13/11
INDIAN CREEK PUMPING STATION, MANKATO, MINNESOTA, HYDRAULIC MOD--ETC(U)
JUN 78 B P FLETCHER
UNCLASSIFIED WES-TR-H-78-8 NL

1 OF 1
AD
A056 687




1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

LEVEL II

12

SC

TECHNICAL REPORT H-78-8

6

INDIAN CREEK PUMPING STATION MANKATO, MINNESOTA

Hydraulic Model Investigation

by

14 WES-TR-H-78-8

10 Bobby P. Fletcher
Hydraulics Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

12 52p.

11 Jun[redacted]978

9 Final Report. Mar 76-May 77,

Approved For Public Release; Distribution Unlimited

Prepared for U. S. Army Engineer District, St. Paul
St. Paul, Minnesota 55101

78 07 17 134

Ø38 1ØØ

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Technical Report H-78-8	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) INDIAN CREEK PUMPING STATION, MANKATO, MINNESOTA; Hydraulic Model Investigation		5. TYPE OF REPORT & PERIOD COVERED Final report 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Bobby P. Fletcher		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Army Engineer Waterways Experiment Station Hydraulics Laboratory P. O. Box 631, Vicksburg, Mississippi 39180		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Army Engineer District, St. Paul 1135 USPO & Custom House St. Paul, Minnesota 55101		12. REPORT DATE June 1978 13. NUMBER OF PAGES 91
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Entrances (Fluid flow) Flow characteristics Hydraulic models Indian Creek Pumping Station Pumping stations		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The model study was conducted to evaluate the characteristics of inflow to the original design gravity-flow section and pump sump and to develop modifications required for improving the distribution of flow to the gravity-flow section and pump intakes. The 1:10-scale model indicated the need for certain minor modifications to improve flow characteristics in the forebay and ensure satisfactory flow characteristics and pressures near the pump intakes. The major problems (Continued)		

CONT

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

78 07 17 134

20. ABSTRACT (Continued).

Cont

encountered at the pump intakes were generated by the concentrated jet entering and passing through the forebay. The concentrated jet produced adverse currents and turbulence near the pump intakes. Satisfactory approach flows were obtained by installing divider walls to isolate each pump.

The major problems encountered at the entrance to the gravity-flow section were generated by the abrupt transition from the forebay to the gravity-flow section. The problems were alleviated by streamlining the entrance to the gravity-flow section.

The improved flow conditions at the entrance to the gravity-flow section reduced the severe drawdown at the right abutment and provided a more direct route for flow to enter the gravity-flow section.

The improved flow conditions to the pump intakes eliminated surface vortexes and reduced the pressure fluctuations from about 3.6 ft of water with the original design to 1.0 ft of water with the recommended design. Freewheeling propellers, with zero pitch blades, located in the approximate position of the prototype pump propeller indicated a reduction in swirl from 7.6 rpm with the original design to 0.3 rpm with the recommended design.

PREFACE

The model investigation reported herein was authorized by the Office, Chief of Engineers (OCE), U. S. Army, on 4 March 1976, at the request of the U. S. Army Engineer District, St. Paul.

The study was conducted during the period March 1976 to May 1977 in the Hydraulics Laboratory of the U. S. Army Engineer Waterways Experiment Station (WES) under the direction of Messrs. H. B. Simmons, Chief of the Hydraulics Laboratory, and J. L. Grace, Jr., Chief of the Structures Division, and under the direct supervision of Mr. N. R. Oswalt, Chief of the Spillways and Channels Branch. The engineer in immediate charge of the model was Mr. B. P. Fletcher, assisted by Mr. R. L. Bryant. The report was prepared by Mr. Fletcher.

During the course of the investigation, Messrs. Sam Powell, John Robertson, and Robert Kinsel of OCE; Joe Jacobazzi, John Suhm, Jose Ordonez, and Fred Korbus of the North Central Division; and Jim Muegge, Robert Penniman, Martin Farber, and Tom Pennaz of the St. Paul District visited WES to discuss the program of model tests, observe the model in operation, and correlate test results with design studies.

Directors of WES during the conduct of the study and the preparation and publication of this report were COL G. H. Hilt, CE, and COL John L. Cannon, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI)
UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	25.1	millimetres
feet	0.3048	metres
miles (U. S. statute)	1.609344	kilometres
acres	4046.856	square metres
square miles (U. S. statute)	2.589988	square kilometres
gallons per minute	3.785412	cubic decimetres per minute
feet per second	0.3048	metres per second
cubic feet per second	0.02831685	cubic metres per second

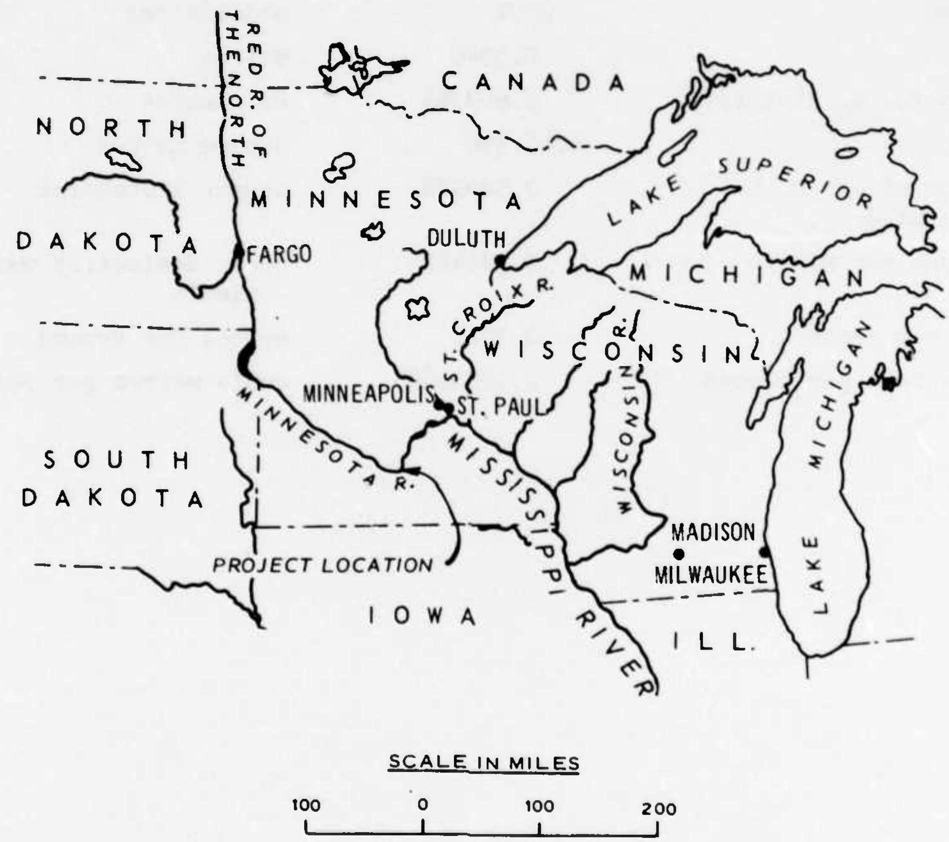


Figure 1. Location map

INDIAN CREEK PUMPING STATION, MANKATO, MINNESOTA

Hydraulic Model Investigation

PART I: INTRODUCTION

The Prototype

1. The Indian Creek storm-water pumping station will be located about 70 miles* southwest of Minneapolis, at Mankato, Minnesota, at the junction of Indian Creek with the Minnesota River on the right bank of the Minnesota River about 480 ft downstream from U. S. Highway 169 bridge (Figure 1 and Plates 1 and 2). The Indian Creek watershed covers about 5722 acres (8.9 square miles). The pumping station can be set for manual or automatic operation and will be used for pumping storm-water runoff only. Details of the original design pumping station are shown in Plate 3.

2. The Pleasant Street ponding area located about 3000 ft upstream of the pumping station (Plate 2) will control the runoff from the upper areas of the watershed. Runoff from the 333-acre drainage area between the ponding area and the pumping station will flow directly to the pumping station via closed conduit and open channel. The proposed pumping station will be of the wet-pit (sump) type and will employ four vertical shaft pumps to provide a pumping capacity of 136,000 gpm. Trashracks will be provided for protection of all pumps. The pumps discharge directly to a common gate well outflowing to the river during blocked gravity drainage conditions.

3. The outlet gates of the Pleasant Street ponding area will be remote-controlled from the pumping station. During flood periods, the gates will normally be closed; however, stored water may be used to augment flows to the pumping station. Peak release rates from the ponding

---

* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.

area will not exceed 300 cfs. The station will include three 7-ft square conduits that will convey gravity flows to the river. During potential flood periods when the river reaches el 761,* the sluice gates in the gravity-flow outlets will be closed, the four sluice gates at the entrance to the pump sump will be opened, the pumps will be activated, and the water level in the sump will be pumped to minimum sump elevation (el 757).

Purpose of Model Study

4. The model study was conducted to evaluate the characteristics of pumped and gravity flows in the original design pumping station and to develop modifications required for improving the distribution of flow to the pump intakes and gravity-flow outlets.

* All elevations (el) cited herein are in feet referenced to mean sea levels (1929 adjustment).

PART II: THE MODEL

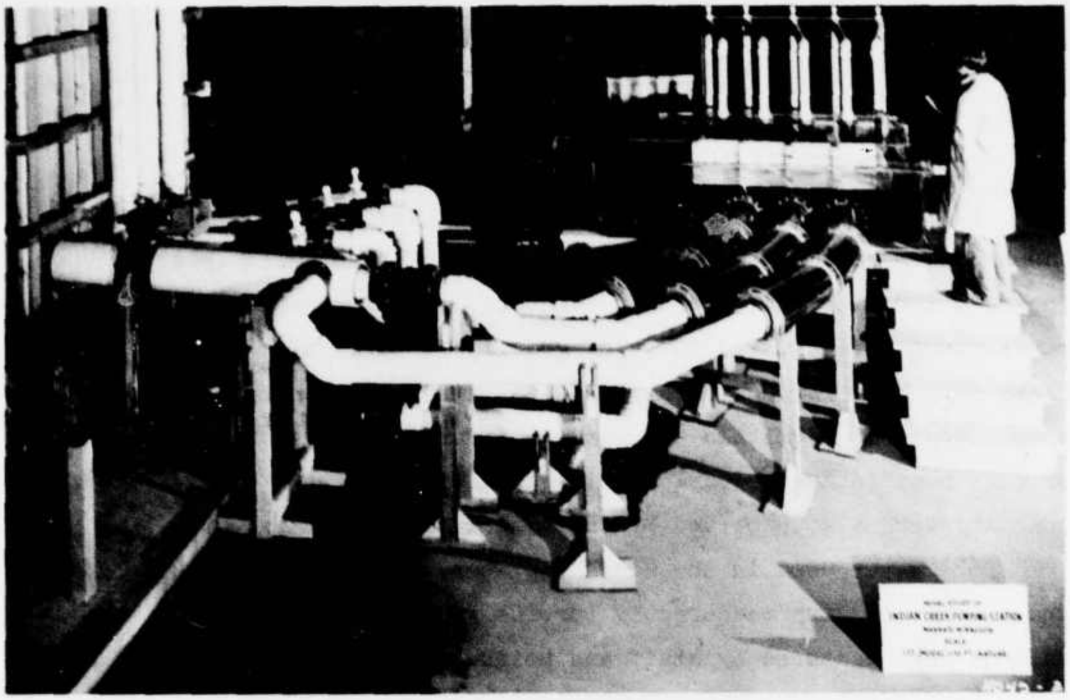
Description

5. The model of Indian Creek pumping station, constructed to a linear scale ratio of 1:10, was fabricated of transparent plastic and included 100 ft of the approach conduits, sump forebay, pump sump, trash-racks, pump intakes, and 50 ft of gravity-flow conduits (Figure 2 and Plate 3). Flow through each pump intake was provided by individual suction pumps that permitted simulation of various flow rates through one or more pump intakes. Various flow conditions through the gravity-flow conduits were also provided by individual suction pumps.

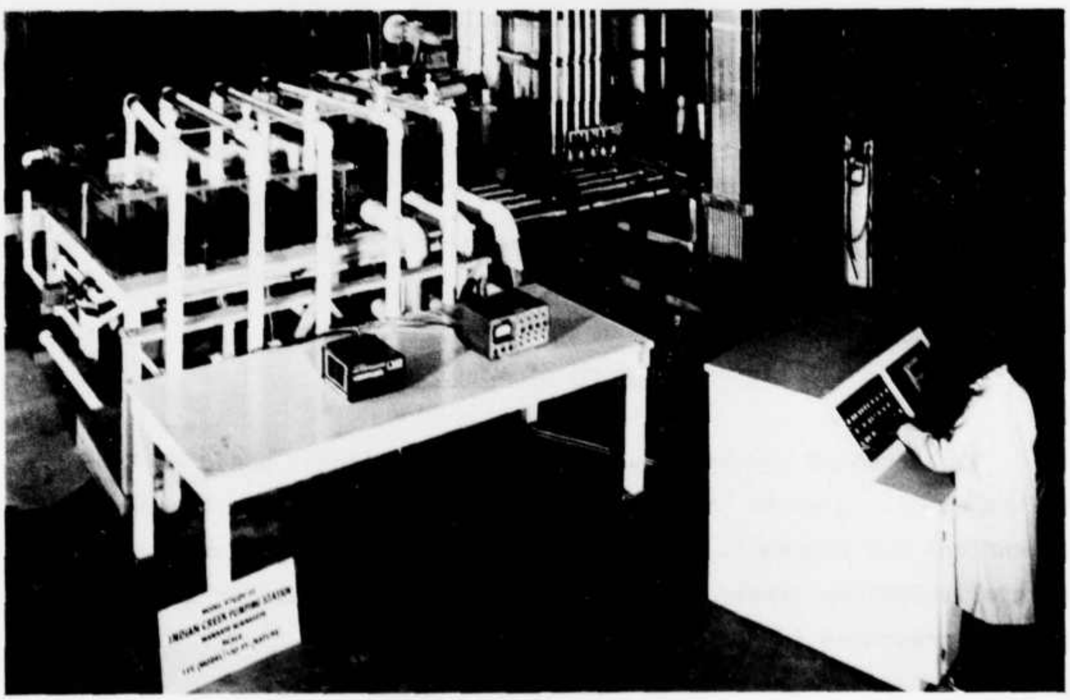
6. Water used in the model was stored and recycled in a headbox and discharges were measured by turbine flowmeters. Water-surface elevations were measured by staff and point gages. Velocities were measured by a pitot tube and a turbine current meter. Current patterns were determined by dye injected into the water and confetti sprinkled on the water surface. Pressure fluctuations at the pump intakes were measured by 5.0-in.-diam (prototype) electronic pressure cells (Figure 3) flush with the floor of the sump directly below the center line of the pump column. Swirl in the pump intakes was measured by vortimeters (freewheeling propellers with zero pitch blades) located inside each pump intake at the approximate position of the prototype pump propeller (Figures 4 and 5).

Interpretation of Model Results

7. Accepted equations of hydraulic similitude, based on Froudian criteria, were used to express the mathematical relations between the dimensions and hydraulic quantities of the model and prototype. The general relations expressed in terms of the model scale or length ratio, L_r, are presented in the tabulation on page 10:



a. Inflow to pumping station



b. Outflow from pumping station

Figure 2. The 1:10-scale model

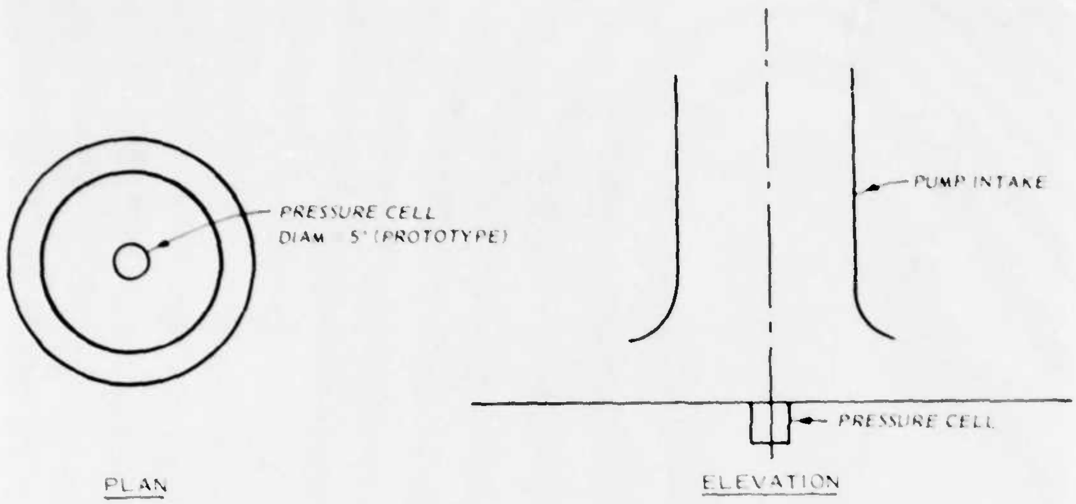


Figure 3. Pressure cell location

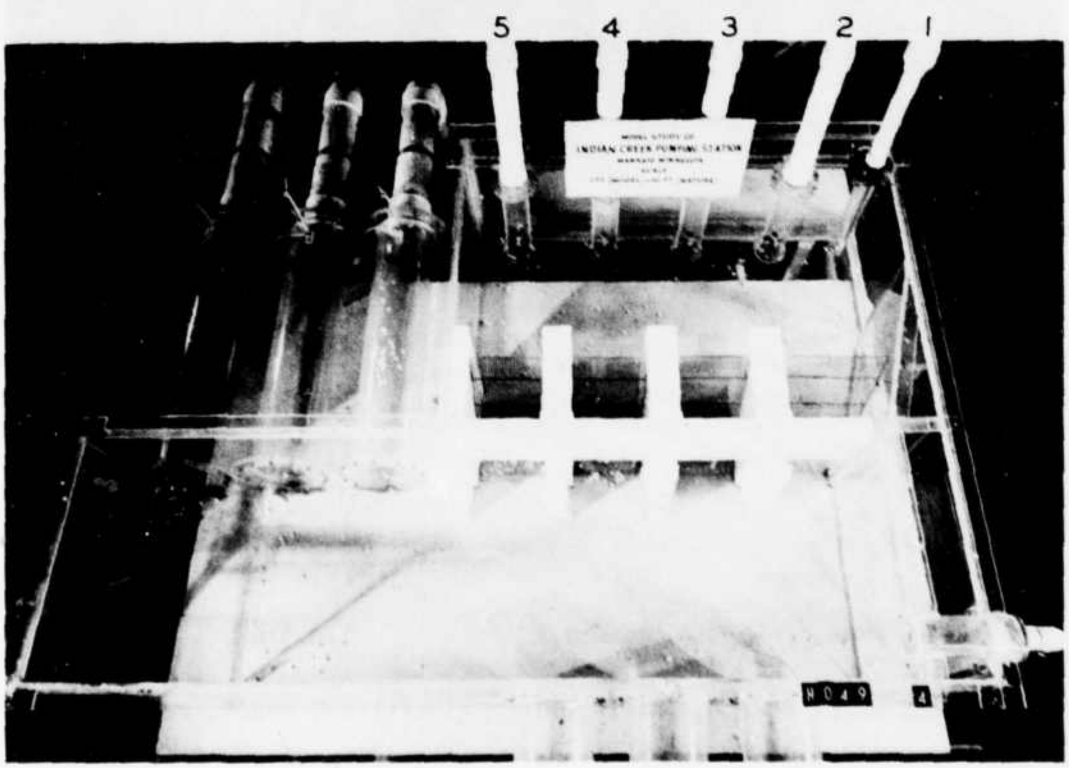


Figure 4. Plan of original design pumping station

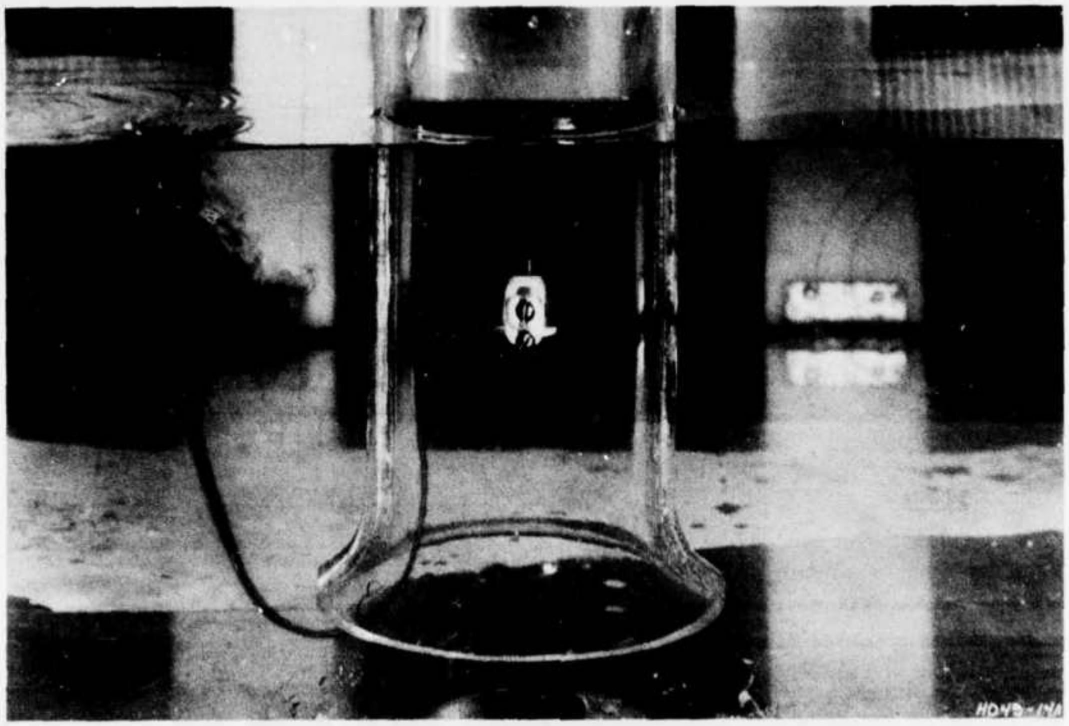


Figure 5. Flow conditions; original design, pumps 2 and 3 operating, sump el 757

Dimension	Ratio	Scale Relation
Length	L_r	1:10
Area	$A_r = L_r^2$	1:100
Velocity	$V_r = L_r^{1/2}$	1:3.16
Discharge	$Q_r = L_r^{5/2}$	1:316.23
Time	$T_r = L_r^{1/2}$	1:3.16
Pressure	$P_r = L_r$	1:10
Frequency	$f_r = 1/L_r^{1/2}$	1:0.316

Measurement of discharge, water-surface elevations, heads, velocities, pressure, and frequency can be transferred quantitatively from the model to prototype equivalents by these scale relations.

PART III: TESTS AND RESULTS

Original Design

8. The 1:10-scale reproduction of the original design of the gravity-flow section and the pump sump including the four 36-in. pumps, the 24-in. pump, and the 24-in. return flow conduit is shown in Figure 4. The pumps were numbered as indicated in Figure 4. The 24-in. pump (pump 1) had a 15,000-gpm capacity and was designed to pump during periods of low inflow. Each 36-in. pump had a capacity of 34,000 gpm. Pump 2 could return as much as 15,000 gpm to the sump through the 24-in. return flow conduit to reduce pump cycling. Hydraulic performance of the pump sump and gravity-flow outlet were evaluated by visual observations of flow conditions and measurements of velocities and flow distributions, pressures on the floor of the sump directly below the vertical axis of the pump columns, and rotation of flow at the approximate position where each propeller will be located in the prototype.

9. Various pump-induced flow conditions are illustrated in Photos 1-7. Inflow from the three conduits tended to remain concentrated in the central portion of the forebay and sump. This uneven flow distribution produced counter eddies on opposite sides of the sump (Photos 4-7) that induced adverse circulation in the vicinity of the pump intakes. Air-entraining vortexes (Figure 5) occurred intermittently at the pump intakes. Figure 6 shows the stages in the development of an air-entraining vortex from a small depression in the water surface which gradually becomes deeper until air bubbles intermittently break away, forming a continuous air core extending into the pump intake. Adverse currents in the sump were amplified when the return flow from pump 1 was discharged into the forebay normal to the inflow current (Photo 8). The presence of the trashracks did not affect the flow. Pressure fluctuations expressed as feet of water and rotational flow tendencies expressed as revolutions per minute in the prototype intakes and pumps are given in Table 1. The majority of the measurements

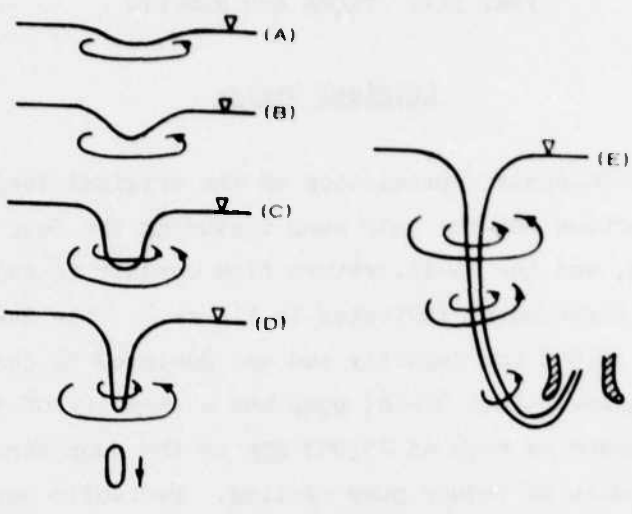


Figure 6. Stages in development of air-entraining vortex

indicate that the pressure fluctuations may be related to the speed of the vortimeter or rotation of flow.

10. With the gates to the pump sump closed and the maximum anticipated discharge of 995 cfs through the gravity-flow section, a severe contraction of flow occurred at the right abutment as illustrated in Photo 9. The contraction appeared to cause significant head loss in flow through the gravity-flow section.

Alternate Designs

11. Several designs were investigated to develop one that would uniformly distribute water to the pump intakes and provide satisfactory flow to the gravity-flow section. Flow separation at the pier noses was reduced by adding 1-ft radii to the noses of the piers as shown in Plate 4. Flow was more evenly dispersed in the forebay and uniformly distributed to the pump intakes by the baffle shown in Plate 4. The baffle also improved the flow distribution when flow was being recycled to the sump through pump 1 and the return flow conduit. However, adverse currents in the sump and intermittent nonair-entraining vortexes were observed in the vicinity of the pump intakes. Adverse flow

patterns that occurred due to the return flow and the unsymmetrical geometry of the pump sump were improved by adding the divider wall (type 1) shown in Plate 4. However, the divider wall isolated the 24-in. pump and created adverse flow conditions in pump bay 1 when the pump was operating.

12. The performance of the gravity-flow section was improved by extending the gravity-flow conduits and positioning the headwall 4.5 ft upstream as shown by the dashed lines in Plate 4. This modification provided a more direct route and reduced contraction of flow entering the gravity-flow conduits.

13. The type 2 divider wall with a rounded nose (Plate 5) was installed in the model, and less contraction of flow was observed around the nose of the divider wall and more uniform flow distribution resulted inside the 24-in. pump bay. Although the type 2 divider wall was a significant improvement, surface eddies tended to exist in the vicinity of the pump column. A hanging baffle was installed 3 ft downstream from the entrance to the 24-in. pump bay (Plate 5). The lower part of the baffle extended down to el 755, 2 ft below the minimum sump elevation. Flow accelerated as it passed below the baffle and was more uniformly distributed inside the pump bay. No surface eddies were observed in the vicinity of the 24-in. pump.

14. Additional modifications were investigated in an attempt to improve flow distribution to the four 36-in. pumps. The type 2 baffle was installed across the forebay as shown in Plate 6a, but tests revealed this modification did not significantly improve flow distribution. The type 2 baffle provided satisfactory flow distribution to the gravity-flow section with all discharges, including the maximum rate of 995 cfs.

15. The type 3 baffle was installed across the forebay (Plate 6b) to provide a more uniform flow distribution with all combinations of pumps operating at anticipated sump elevations. Water-surface depressions similar to stage (c) in Figure 6 were evident in the vicinity of each of the four 36-in. pump intakes. Although the type 3 and several other baffle designs investigated improved the hydraulic performance of the sump, none were considered satisfactory.

16. Tests were conducted to investigate the effects of extending the length of the piers downstream. Test results revealed that partial pier extensions toward the back wall induced adverse circulation around the downstream end of the piers. Satisfactory sump performance was achieved with individual bays that were formed by extending the piers to the back wall (Plate 7). Velocity measurements indicated satisfactory velocity distribution in the individual bays, and only intermittent surface depressions with stage (a) vortexes as shown in Figure 6 and Photo 10 were evident in the vicinity of each pump. Although it was considered that this type vortex might not be harmful, tests were conducted to develop a device that would eliminate the vortex. Investigation of several types of vortex suppressors resulted in selection of the type 3 (Plate 7), which eliminated the surface depressions. Pressure fluctuations expressed as feet of water and rotational flow tendencies measured with vortimeters as revolutions per minute in the prototype pumps are given in Table 2. The values indicate a significant reduction in magnitude when compared with the values obtained with the original design (Table 1). Velocities measured with various sump elevations and combinations of pumps operating are presented in Plates 8-28. These velocities were measured 1 ft above the floor of the sump and indicate the lateral flow distribution approaching the pumps.

Recommended Design

17. Engineers of the U. S. Army Engineer District, St. Paul, decided, for reasons of economy, to eliminate the 15,000 gpm (24 in.) pump and revise the cross section of the three gravity-flow discharge conduits from 8 ft in diameter to 7 ft square. The recommended pumping station design (Plate 29) was developed by incorporating these modifications. Various flow conditions with the recommended design are illustrated in Photos 11-19. The trashrack has an insignificant effect on hydraulic performance and should be used for all bays. Velocities measured with various sump elevations and combinations of pumps operating are presented in Plates 29-48 and indicate that the recommended sump

design should provide satisfactory flow distribution to the pumps. Pressure fluctuations and rotational flow tendencies observed with the recommended design are given in Table 3. The values in Table 3 and Photo 20 indicate essentially no flow instability or swirl at the pump intakes. A comparison of Table 1 (original design) and Table 3 (recommended design) indicates a reduction in maximum pressure fluctuations from 3.6 ft (original design) to 1.0 ft of water (recommended design) and a reduction in swirl from 7.6 rpm (original design, prototype speed) to 0.3 rpm (recommended design). The type 3 vortex suppressors (Plates 7-29) eliminated any tendency for surface vortexes as illustrated by dye injected into the flow in Photo 21.

18. Satisfactory flow conditions were observed for all anticipated flow conditions with the three 7-ft square conduits (type 3 gravity-flow intakes) shown in Plate 29. Performance with the maximum anticipated flow of 995 cfs is illustrated in Photo 22.

PART IV: DISCUSSION

19. Hydraulic performance of the pump sump and gravity-flow section was improved by the addition of minor modifications developed during the model study. Satisfactory operation of the pumps and gravity-flow section should be anticipated due to the elimination of severe flow instability, swirl, and pressure fluctuations in the vicinity of the pump intakes and contraction of flow at the right abutment of the gravity-flow section.

20. The major hydraulic problems encountered were generated by the concentrated inflow that passed through the forebay into the pump sump with one or more pumps operating, and by the adverse geometry and route required for gravity flow from the three inflow conduits to the three outflow conduits. Several alternate designs that included baffles in the forebay to disperse the inflow were unsuccessful.

21. Satisfactory sump flow conditions were obtained by rounding the noses of the piers to reduce separation of flow at entry and by isolating each pump by extending the piers to the back wall of the sump. Pressure cells located on the floor of the sump directly below the center line of each pump intake reflected the improved flow conditions that resulted from the recommended modifications by indicating a reduction in maximum pressure fluctuations from about 3.6 ft of water with the original design to approximately 1.0 ft of water with the recommended design. Freewheeling propellers, with zero pitch blades, located in the approximate position of the prototype pump propeller indicated a reduction in maximum swirl from 7.6 rpm (prototype speed) with the original design to 0.3 rpm with the recommended design. Velocities measured in the approach to the recommended design indicated uniformly distributed flow to the pumps. The severe drawdown of flow at the entrance to the gravity-flow section was eliminated by streamlining the right abutment and providing a more direct route for flow to enter the gravity-flow section.

Table 1

Pressure Fluctuations and Swirl at Pump Intakes, Original Design

Sump El, ft	Sump Performance Indicator	Pump No. 1	2	3	4	5
757	Pressure fluctuation*	X	0.5	X	X	X
	Rotational flow tendency, rpm		0			
757	Pressure fluctuation	X	1.4	2.8	X	X
	Rotational flow tendency, rpm		0	4.2←	X	X
757	Pressure fluctuation	X	1.5	1.0	2.0	X
	Rotational flow tendency, rpm		1.3→	4.4←	7.6←	
757	Pressure fluctuation	X	X	X	X	0.5
	Rotational flow tendency, rpm					2.5→
760	Pressure fluctuation	X	0.2	X	X	X
	Rotational flow tendency, rpm		0			
760	Pressure fluctuation	X	0.5	2.0	X	X
	Rotational flow tendency, rpm		0	3.8←		
760	Pressure fluctuation	X	1.0	0.5	2.8	X
	Rotational flow tendency, rpm		2.5	1.3←	5.7←	
760	Pressure fluctuation	X	1.0	0.5	0.5	0.5
	Rotational flow tendency, rpm		1.9→	0	0	0
760	Pressure fluctuation	X	X	X	X	0.5
	Rotational flow tendency, rpm					1.9→
761	Pressure fluctuation	X	0.2	X	X	X
	Rotational flow tendency, rpm		0			
761	Pressure fluctuation	X	2.0	3.4	X	X
	Rotational flow tendency, rpm		4.4→	7.6←		
761	Pressure fluctuation	X	1.0	0.5	2.0	X
	Rotational flow tendency, rpm		3.0→	0.3←	4.4←	
761	Pressure fluctuation	X	1.0	0.5	0.5	0.5
	Rotational flow tendency, rpm		3.1→	1.3←		
761	Pressure fluctuation	X	X	X	X	0.2
	Rotational flow tendency, rpm					0
762	Pressure fluctuation	X	0.2	X	X	X
	Rotational flow tendency, rpm		0			
762	Pressure fluctuation	X	3.5	2.2	X	X
	Rotational flow tendency, rpm		2.0→	3.8←		
762	Pressure fluctuation	X	2.8	1.0	3.1	X
	Rotational flow tendency, rpm		2.5→	3.3←	8.2←	
762	Pressure fluctuation	X	3.6	1.0	0.5	1.0
	Rotational flow tendency, rpm		5.7→	2.5←	0	0
762	Pressure fluctuation	X	X	X	X	0.2
	Rotational flow tendency, rpm					0

Note: All magnitudes are expressed in terms of prototype equivalents.
→ = clockwise rotation
← = counterclockwise rotation
X = pump not operating
rpm = revolutions per minute
Discharge per pump, 34,000 gpm
* Pressure fluctuations are given in feet of water.

Table 2

Pressure Fluctuations and Swirl at Pump Intakes

Type 2 Divider Wall, Type 1 Pump Bay Wall, Type 3 Vortex Suppressors

Type 2 Pier Noses, and Type 2 Gravity-Flow Intakes

Sump El, ft	Sump Performance Indicator	Pump No. 1	2	3	4	5
757	Pressure fluctuation*	X	0	X	X	X
	Rotational flow tendency, rpm		0.5←			
757	Pressure fluctuation	X	0	0	X	X
	Rotational flow tendency, rpm		0.2←	X		
757	Pressure fluctuation	X	0	0	0	X
	Rotational flow tendency, rpm		0	0	0	
757	Pressure fluctuation	X	2.0	0	0	0
	Rotational flow tendency, rpm		2.0←	0	0	0.3→
757	Pressure fluctuation	**	0	0	0	0
	Rotational flow tendency, rpm		1.0←	0	0	0.5→
757	Pressure fluctuation	X	X	X	X	0
	Rotational flow tendency, rpm					0
757	Pressure fluctuation	X	1.0†	X	X	X
	Rotational flow tendency, rpm		1.5←			
760	Pressure fluctuation	X	0	X	X	X
	Rotational flow tendency, rpm		0.3←			
760	Pressure fluctuation	X	0	0	X	X
	Rotational flow tendency, rpm		0	0		
760	Pressure fluctuation	X	0	0	0	X
	Rotational flow tendency, rpm		0	0	0	
760	Pressure fluctuation	X	0	0	0	0
	Rotational flow tendency, rpm		0	0	0	0.6→
760	Pressure fluctuation	X	X	X	X	0
	Rotational flow tendency, rpm					0

(Continued)

Note: All magnitudes are expressed in prototype equivalents.
→ = clockwise rotation
← = counterclockwise rotation
X = pump not operating
rpm = revolutions per minute

* Pressure fluctuations are given in feet of water.

** Pump No. 1, 15,000 gpm (not instrumented); pumps Nos. 2-5, 34,000 gpm each.

† Pump No. 2, 34,000 gpm, recycling 15,000 gpm to forebay.

Table 2 (Concluded)

Sump El, ft	Sump Performance Indicator	Pump No. 1	2	3	4	5
761	Pressure fluctuation*	X	0.5	X	X	X
	Rotational flow tendency, rpm		0			
761	Pressure fluctuation	X	2.0	2.0	X	X
	Rotational flow tendency, rpm		0	0		
761	Pressure fluctuation	X	1.0	0.5	0	X
	Rotational flow tendency, rpm		0	0	0	
761	Pressure fluctuation	X	1.0	1.0	0	0
	Rotational flow tendency, rpm		0	0	0	0
761	Pressure fluctuation	X	X	X	X	0
	Rotational flow tendency, rpm					0
762	Pressure fluctuation	X	0.5	X	X	X
	Rotational flow tendency, rpm		0			
762	Pressure fluctuation	X	1.0	1.0	X	X
	Rotational flow tendency, rpm		0	0		
762	Pressure fluctuation	X	1.0	1.0	1.0	X
	Rotational flow tendency, rpm		0	0	0	
762	Pressure fluctuation	X	1.0	1.0	1.0	0
	Rotational flow tendency, rpm		0	0	0	0
762	Pressure fluctuation	X	X	X	X	0
	Rotational flow tendency, rpm					0

* Pressure fluctuations are given in feet of water.

Table 3

Pressure Fluctuations and Swirl at Pump Intakes

Type 2 Pump Configuration, Type 1 Pump Bay Wall, Type 3 Vortex Suppressors, Type 2 Pier Noses, and Type 3 Gravity-Flow Intakes

Sump El, ft	Sump Performance Indicator	Pump No. 2	3	4	5
757	Pressure fluctuation*	0	X	X	X
	Rotational flow tendency, rpm	0.2←			
757	Pressure fluctuation	0	0	X	X
	Rotational flow tendency, rpm	0	0		
757	Pressure fluctuation	0	0	0	X
	Rotational flow tendency, rpm	0	0	0	
757	Pressure fluctuation	0.5	0	0	0
	Rotational flow tendency, rpm	0.3←	0	0	0.2→
757	Pressure fluctuation	X	X	X	0
	Rotational flow tendency, rpm				0
760	Pressure fluctuation	0	X	X	X
	Rotational flow tendency, rpm	0			
760	Pressure fluctuation	0	0	X	X
	Rotational flow tendency, rpm	0	0		
760	Pressure fluctuation	0	0	0	X
	Rotational flow tendency, rpm	0	0	0	
760	Pressure fluctuation	0	0	0	0
	Rotational flow tendency, rpm	0	0	0	0
760	Pressure fluctuation	X	X	X	0
	Rotational flow tendency, rpm				0
761	Pressure fluctuation	0.2	X	X	X
	Rotational flow tendency, rpm	0			
761	Pressure fluctuation	1.0	1.0	X	X
	Rotational flow tendency, rpm	0	0		
761	Pressure fluctuation	0.5	0	0	X
	Rotational flow tendency, rpm	0	0	0	

(Continued)

Note: All magnitudes are expressed in prototype equivalents.
← = clockwise rotation
→ = counterclockwise rotation
X = pump not operating
rpm = revolutions per minute
Discharge per pump, 34,000 gpm
* Pressure fluctuations are in feet of water.

Table 3 (Concluded)

Sump El, ft	Sump Performance Indicator	Pump No. 2	3	4	5
761	Pressure fluctuation*	0.5	0.5	0	0.2
	Rotational flow tendency, rpm	0	0	0	0
761	Pressure fluctuation	X	X	X	0
	Rotational flow tendency, rpm				0
762	Pressure fluctuation	0	X	X	X
	Rotational flow tendency, rpm	0			
762	Pressure fluctuation	0.5	0.5	X	X
	Rotational flow tendency, rpm	0	0		
762	Pressure fluctuation	0.5	0.5	0.5	X
	Rotational flow tendency, rpm	0	0	0	
762	Pressure fluctuation	0.5	0.5	0.5	0.5
	Rotational flow tendency, rpm	0	0	0	0
762	Pressure fluctuation	X	X	X	0
	Rotational flow tendency, rpm				0

* Pressure fluctuations are in feet of water.

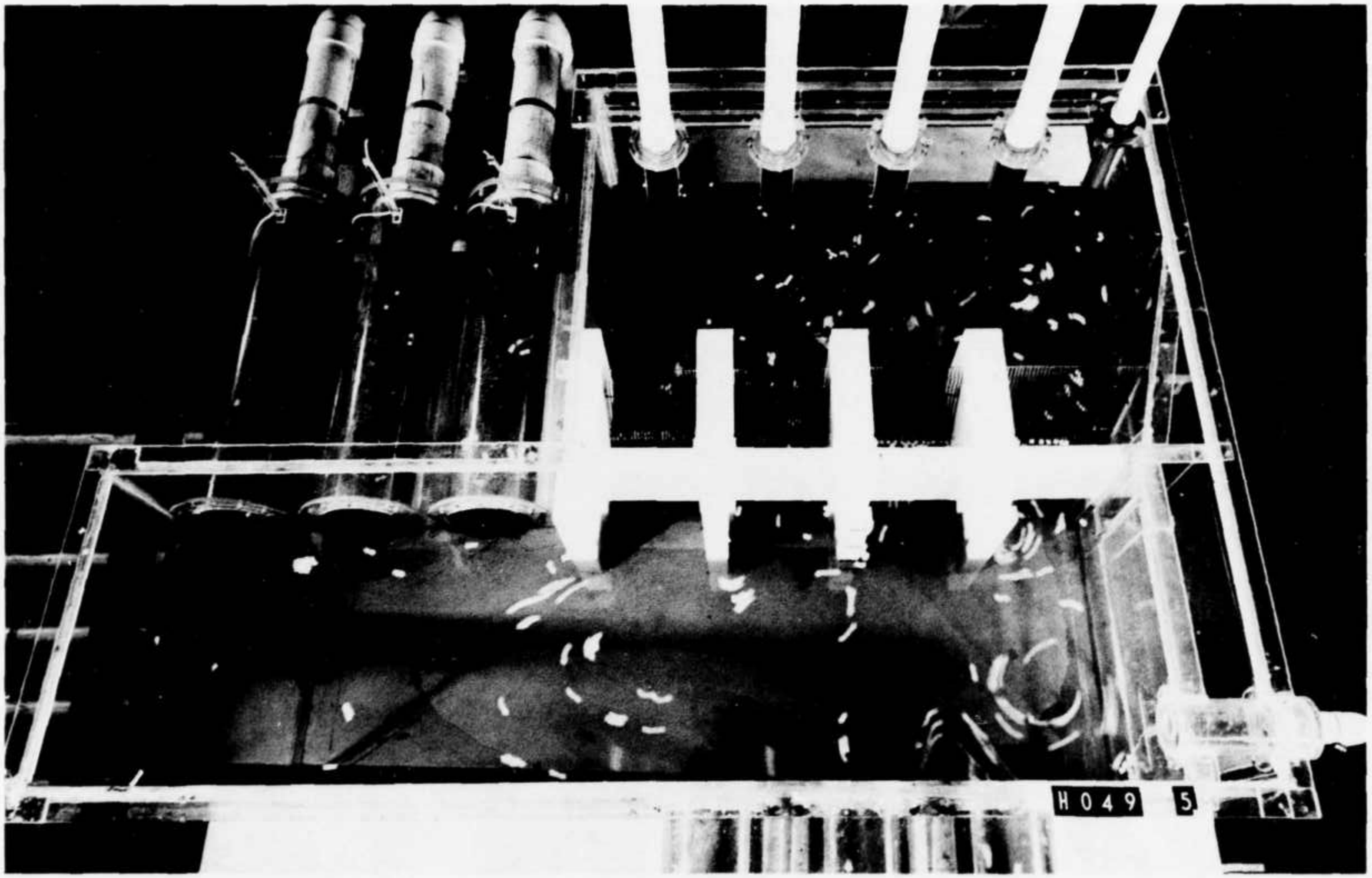


Photo 1. Flow conditions, original design; pump 2 operating, sump el 757

Photo 2. Flow conditions, original design; pumps 2 and 3 operating, sump el 757

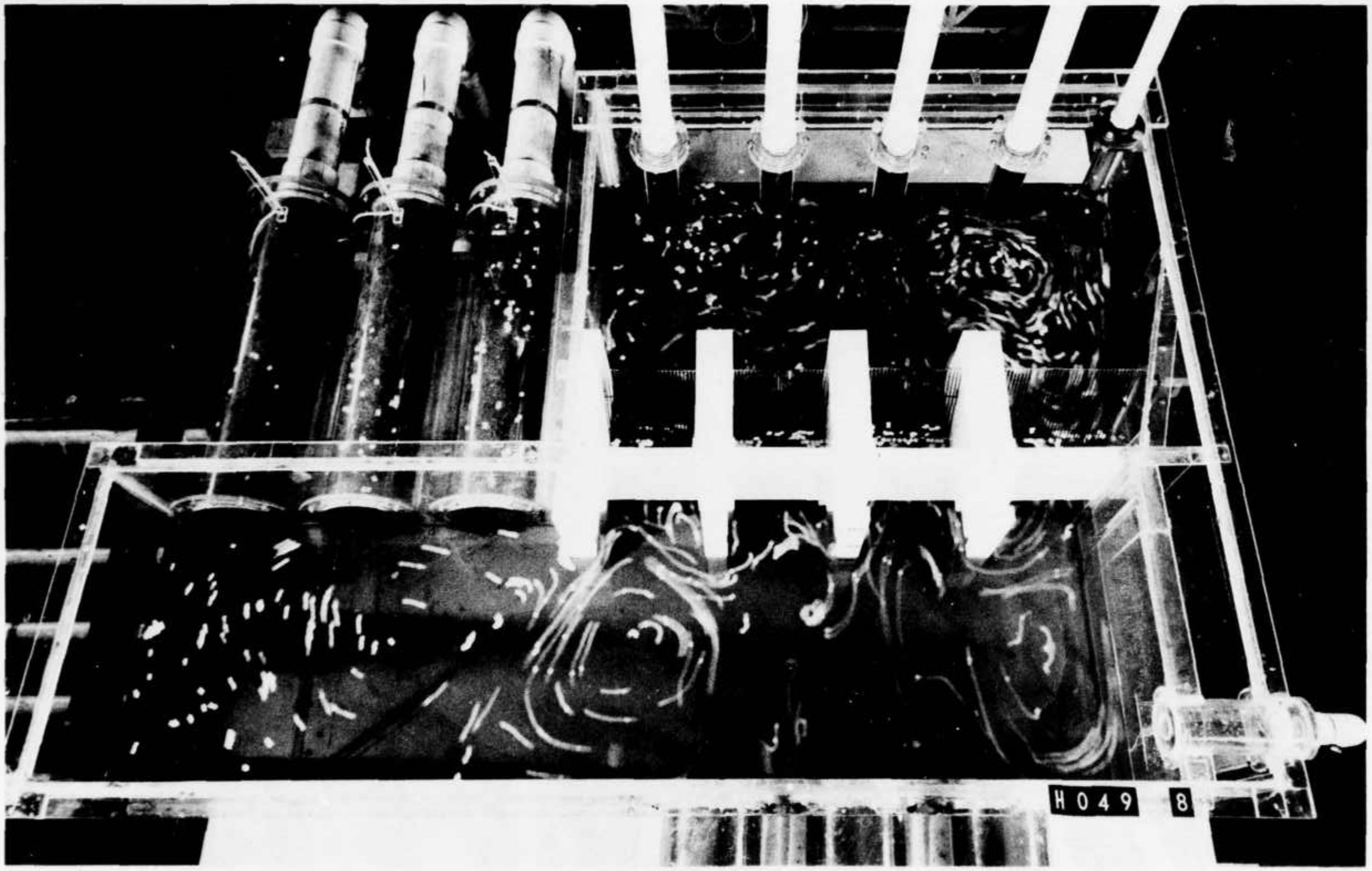


Photo 3. Flow conditions, original design; pumps 2, 3, and 4 operating, sump el 757

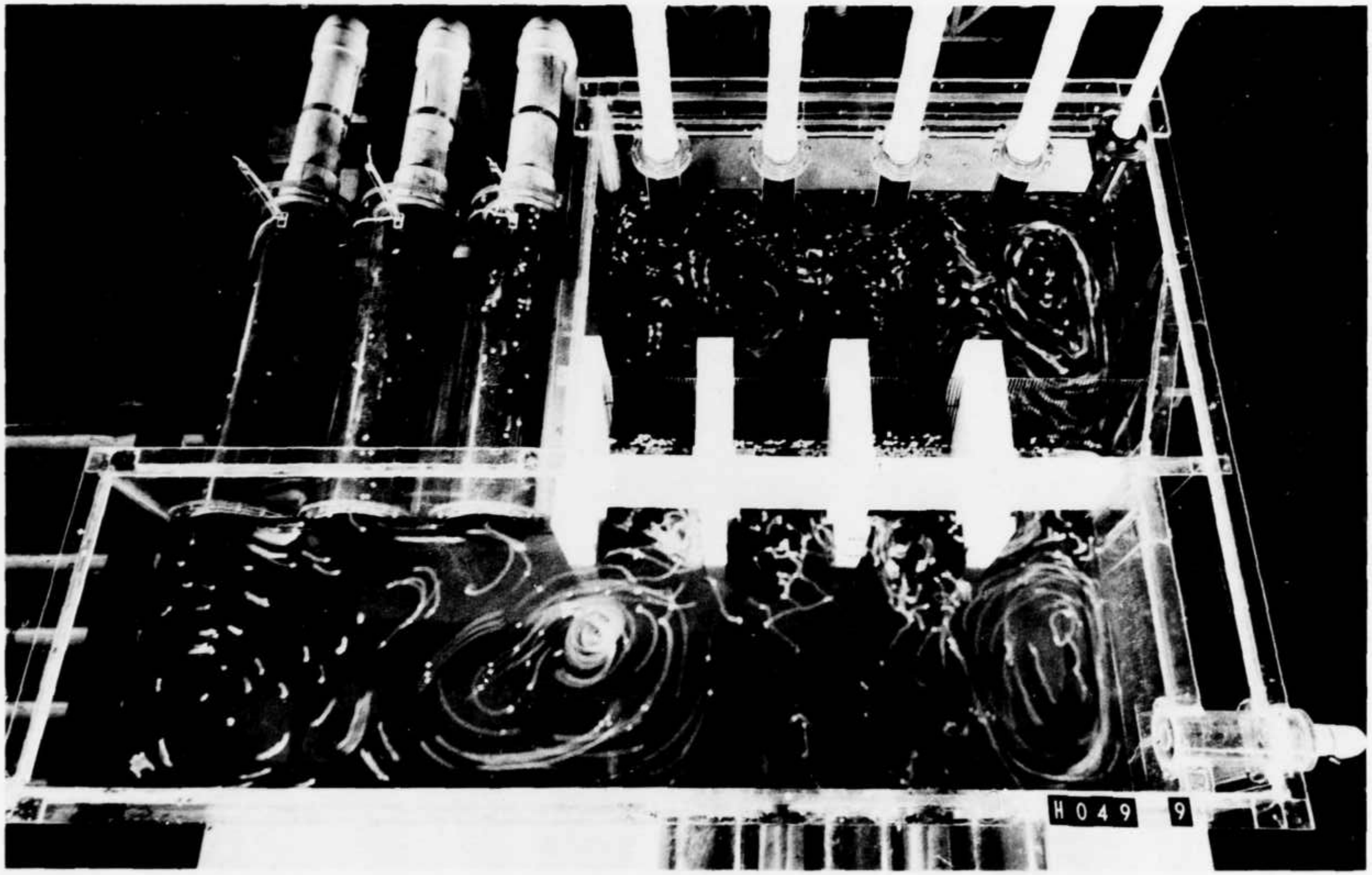


Photo 4. Flow conditions, original design; pumps 2, 3, 4, and 5 operating, sump el 757

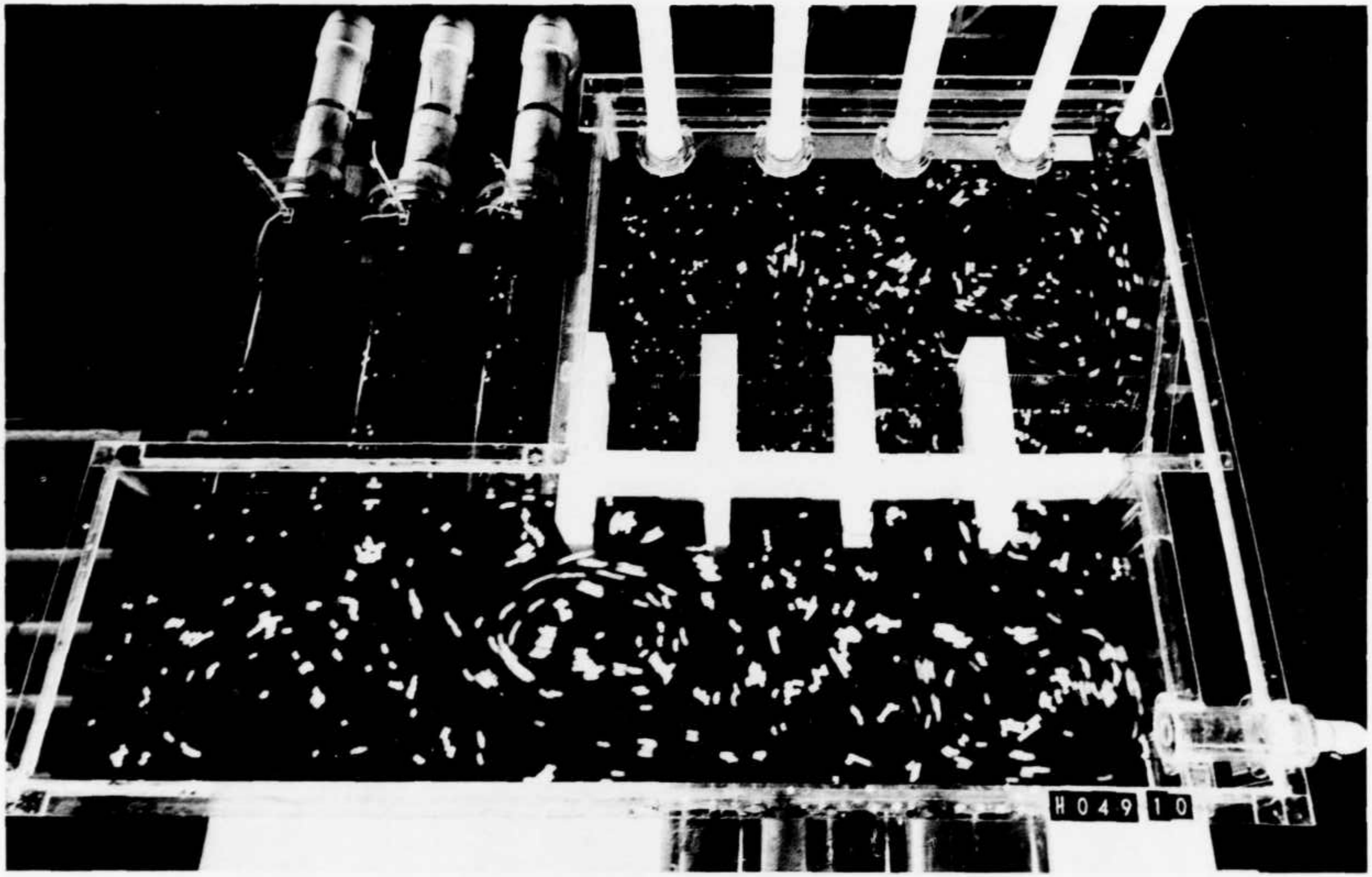


Photo 5. Flow conditions, original design; pump 2 operating, sump el 762

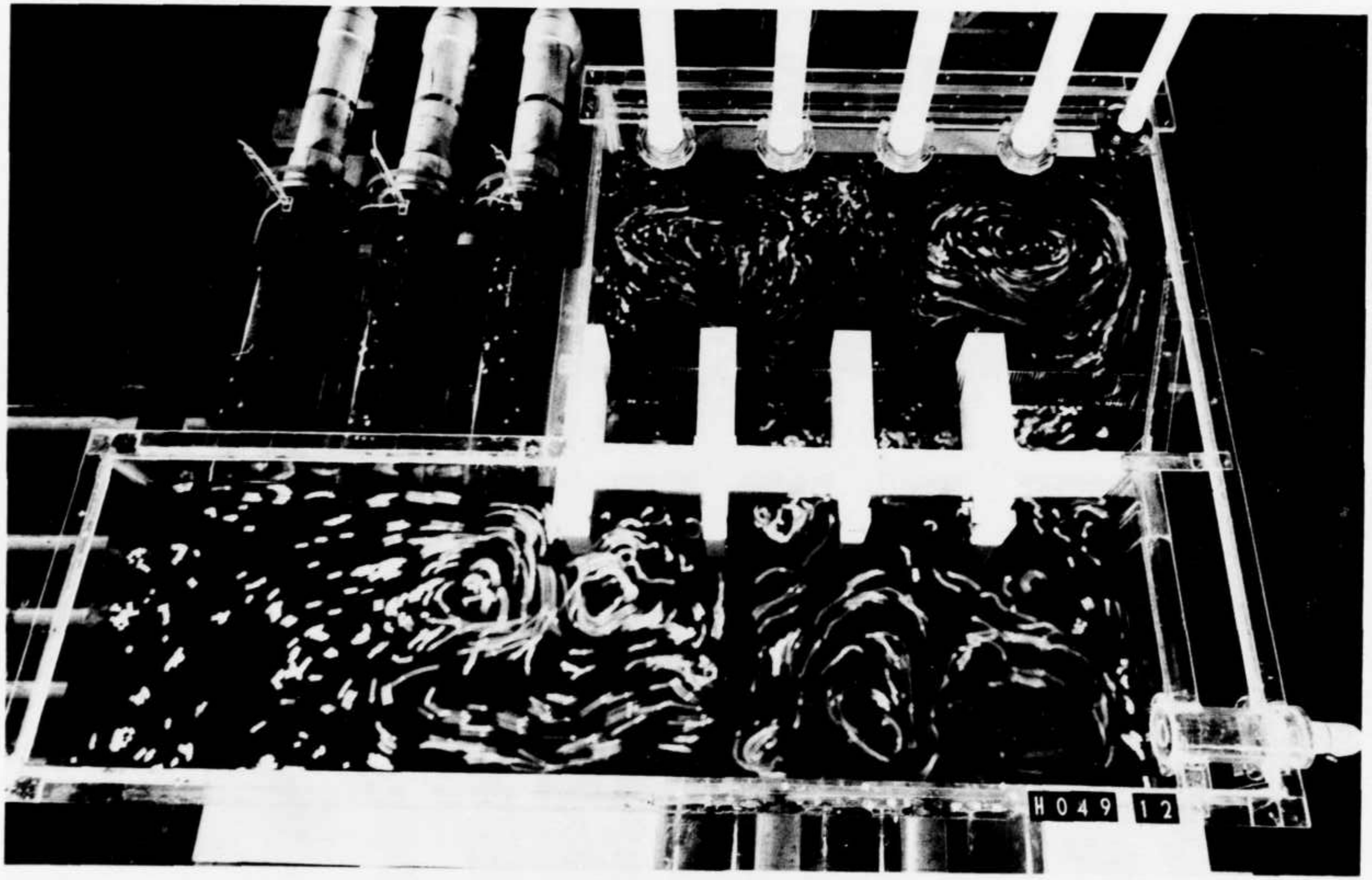


Photo 6. Flow conditions, original design; pumps 2, 3, 4, and 5 operating, sump el 762

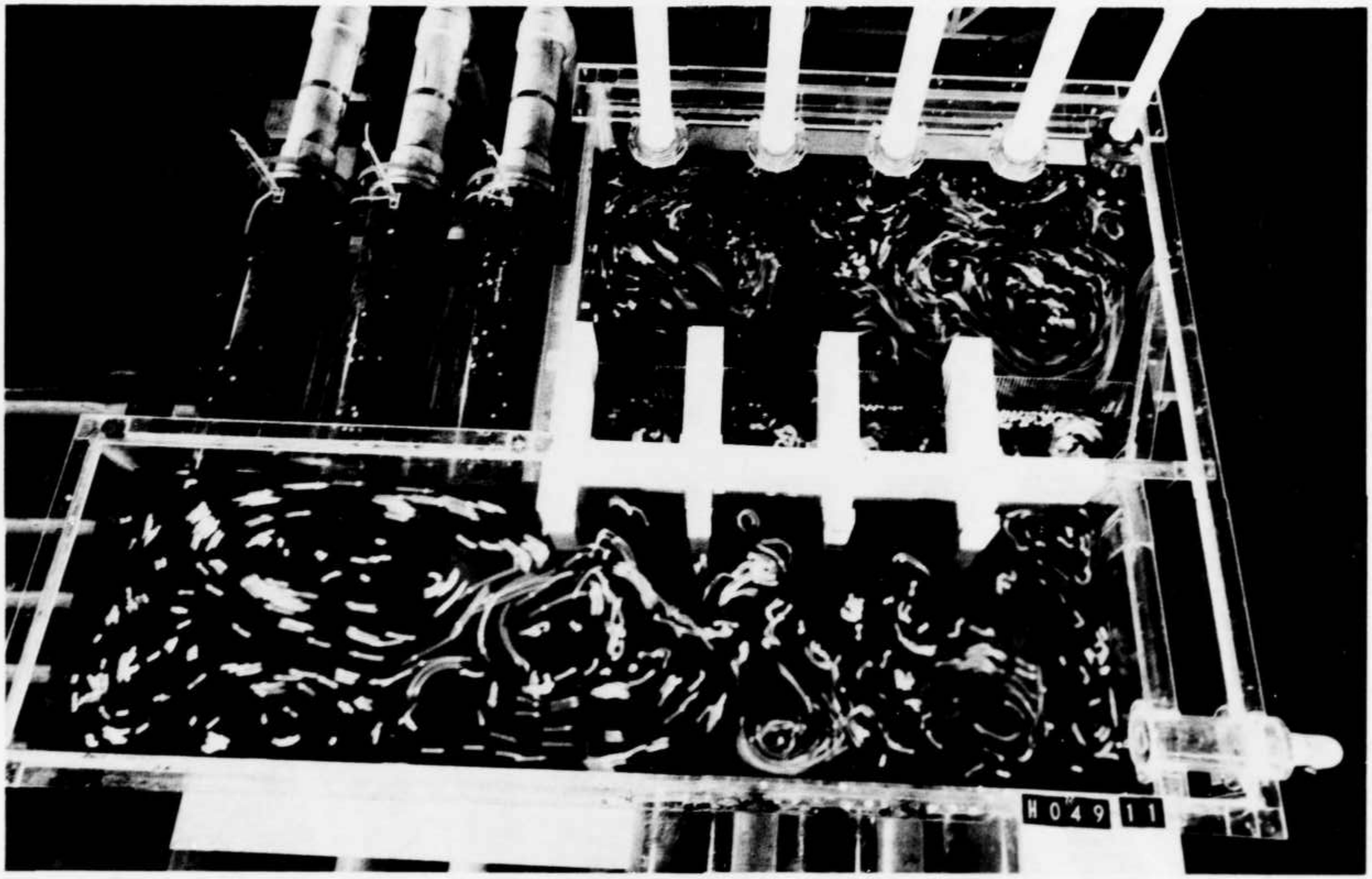


Photo 7. Flow conditions, original design; pumps 1, 2, 3, 4, and 5 operating, sump el 762

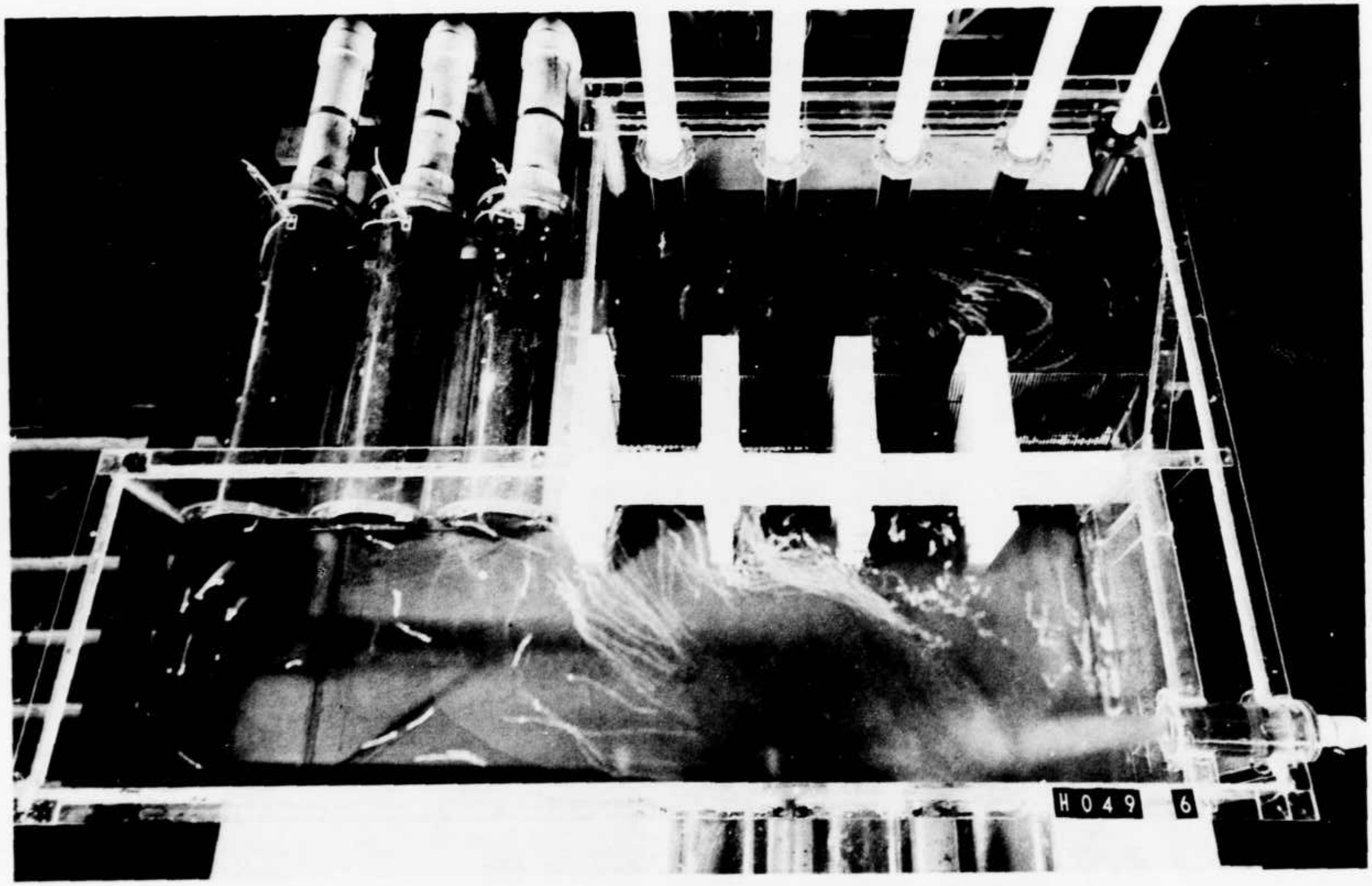


Photo 8. Flow conditions, original design; pump 2 operating, discharge 34,000 gpm, recycle 15,000 gpm, sump el 757

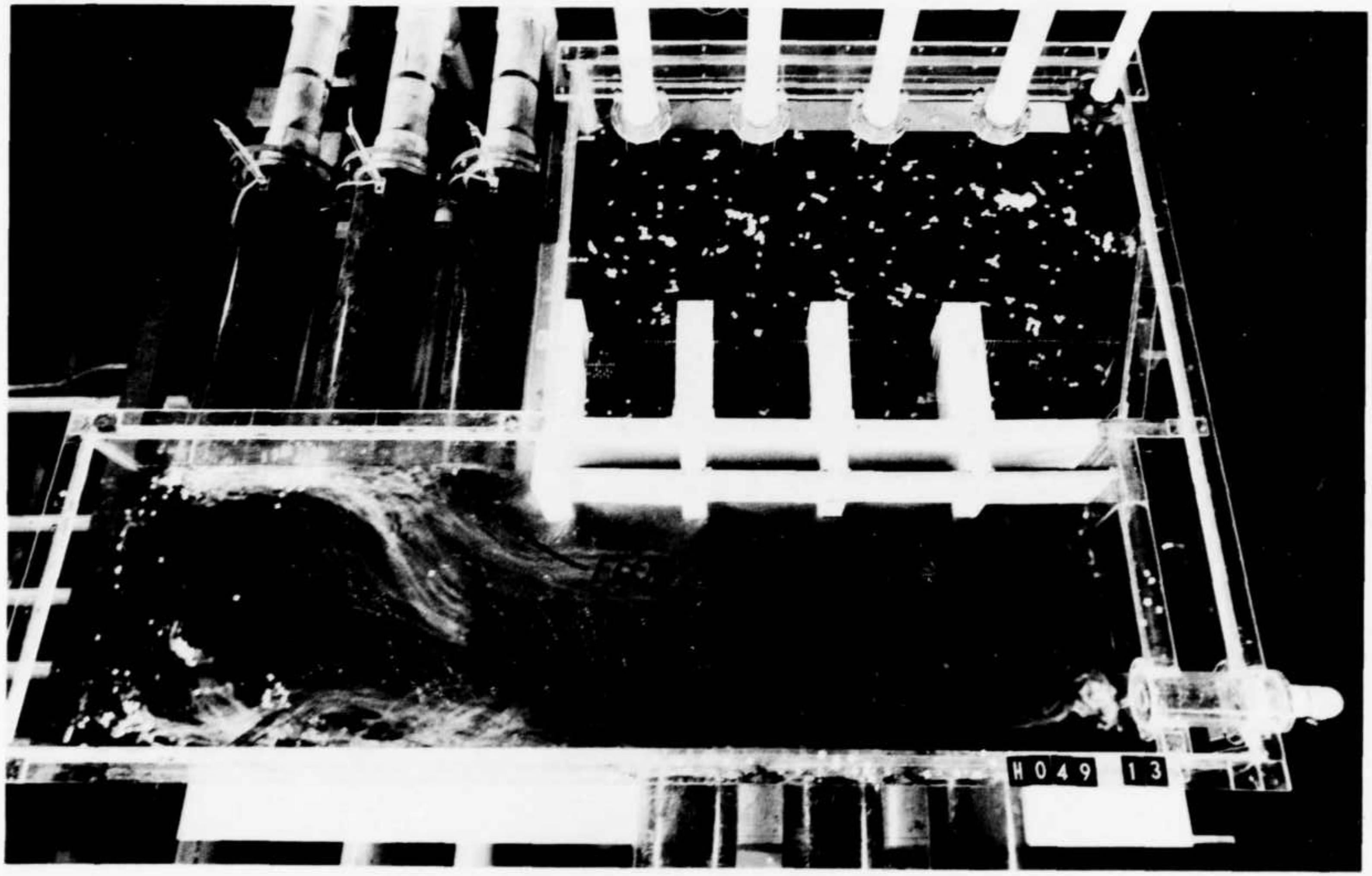


Photo 9. Flow conditions, original design; gravity flow, discharge 995 cfs, sump el 761

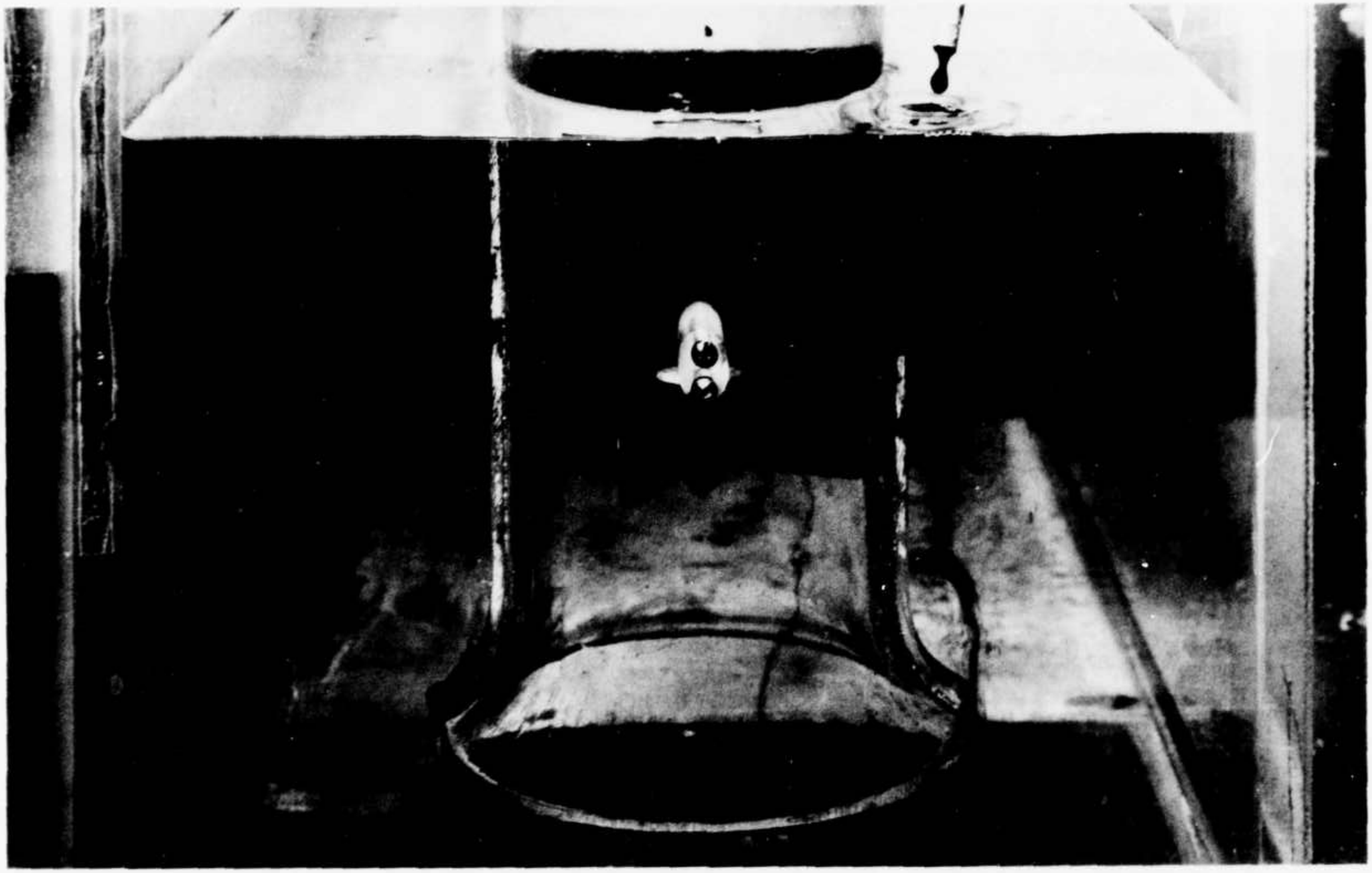


Photo 10. Flow conditions, alternate design; pump 2 operating, discharge 34,000 gpm, sump el 757

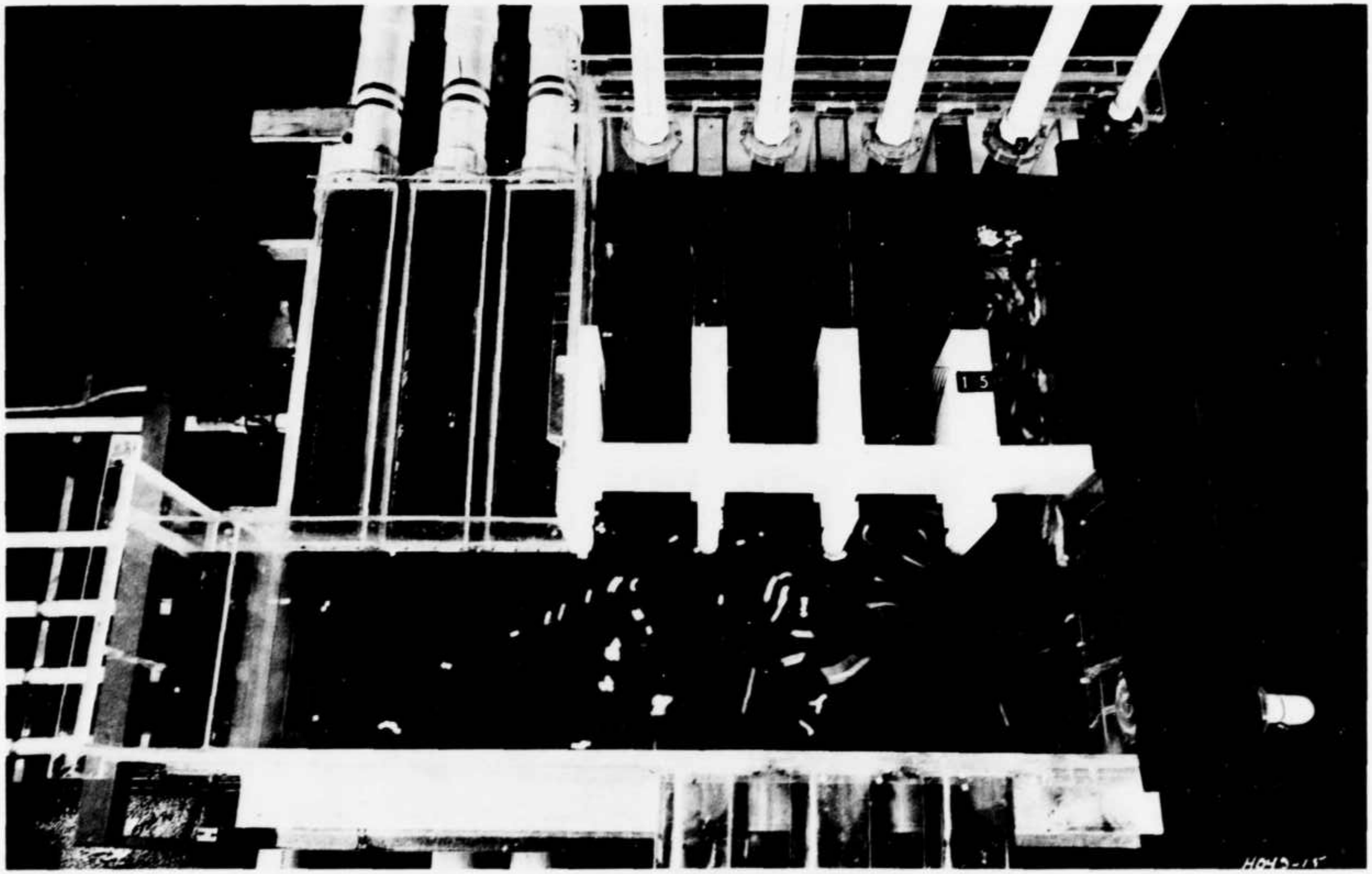


Photo 11. Flow conditions, recommended design; pump 2 operating, discharge 34,000 gpm, sump el 757

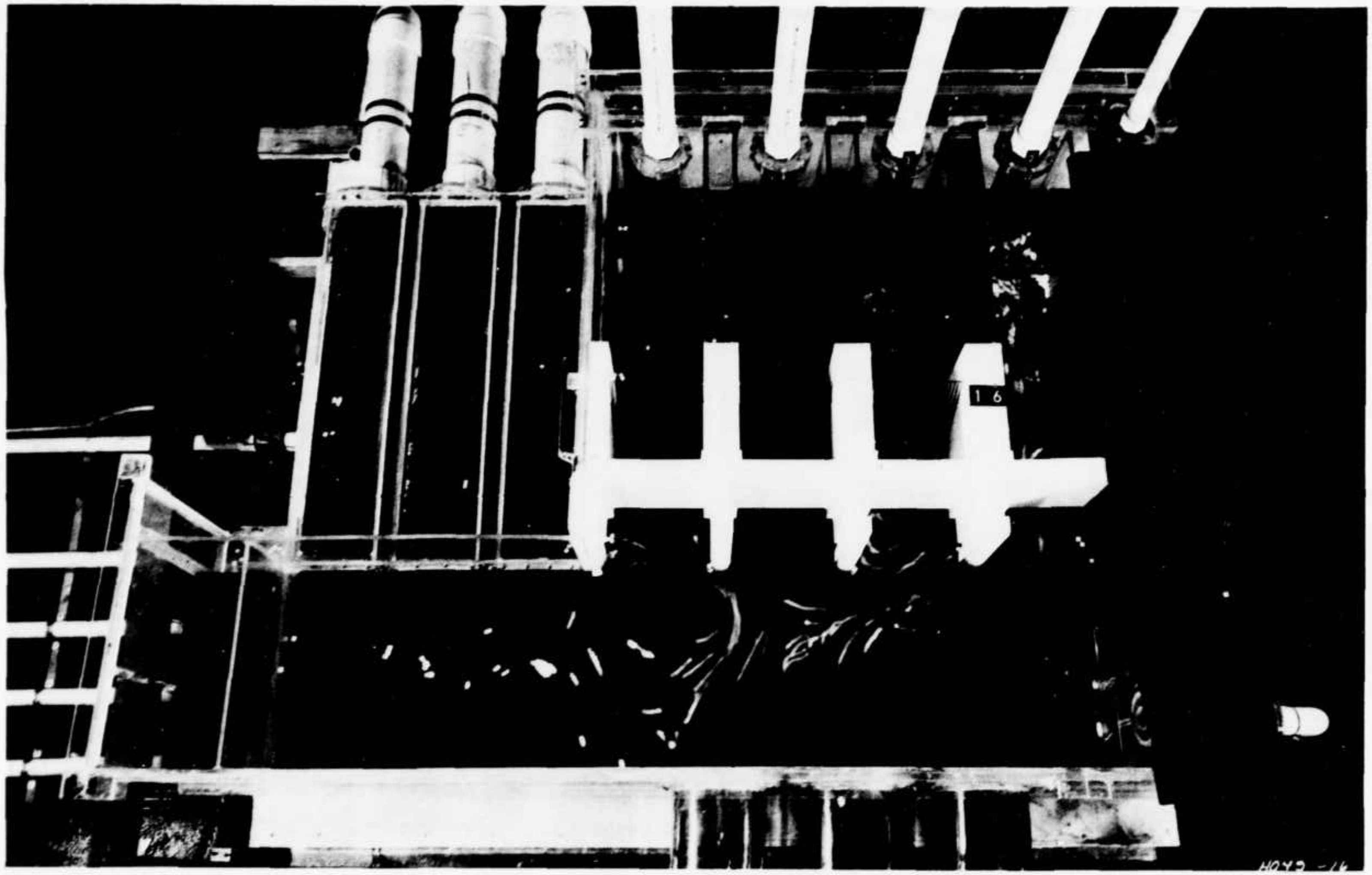


Photo 12. Flow conditions, recommended design; pumps 2 and 3 operating, discharge per pump 34,000 gpm, sump el 757

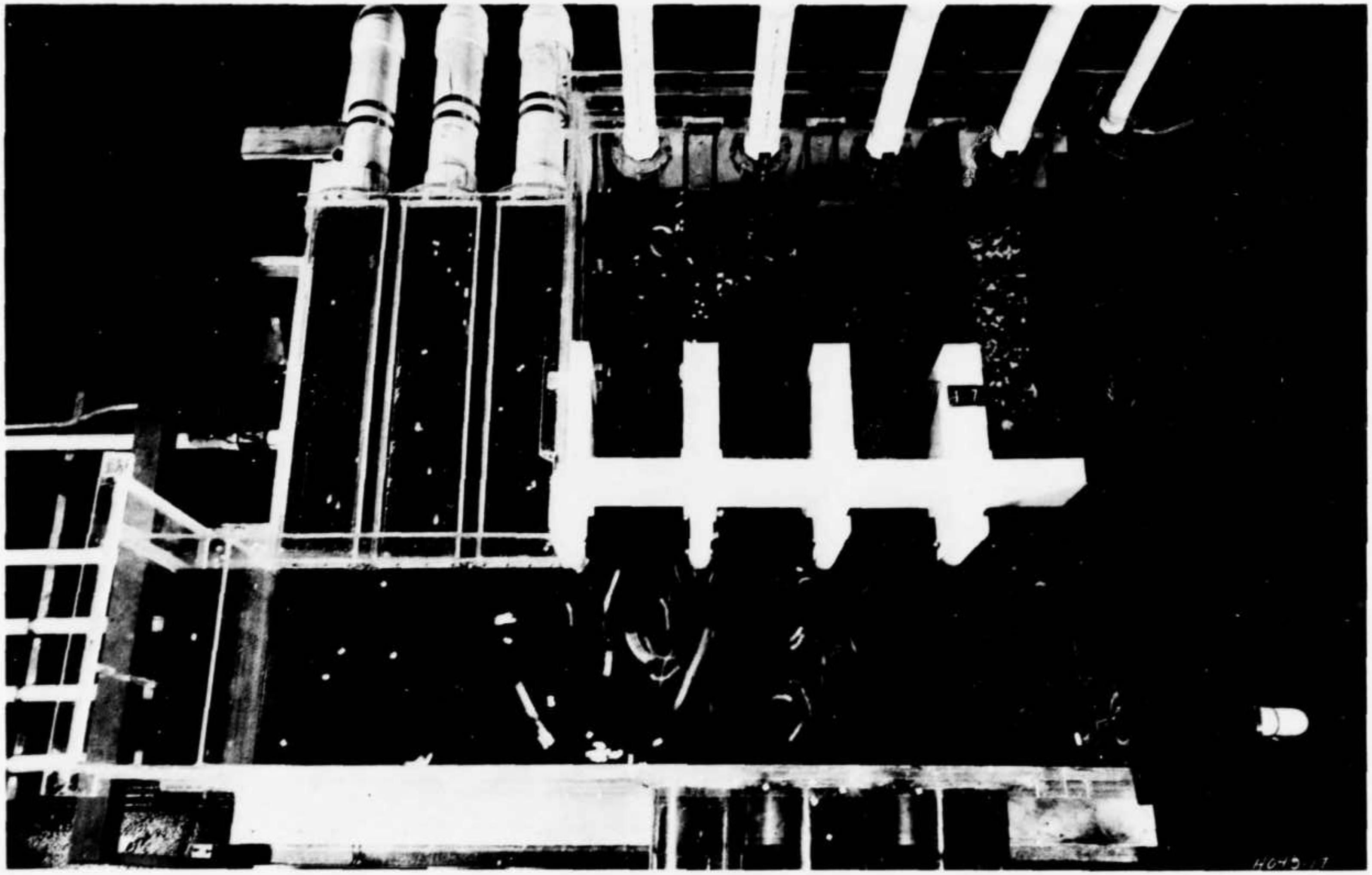


Photo 13. Flow conditions, recommended design; pumps 2, 3, and 4 operating, discharge per pump 34,000 gpm, sump el 757

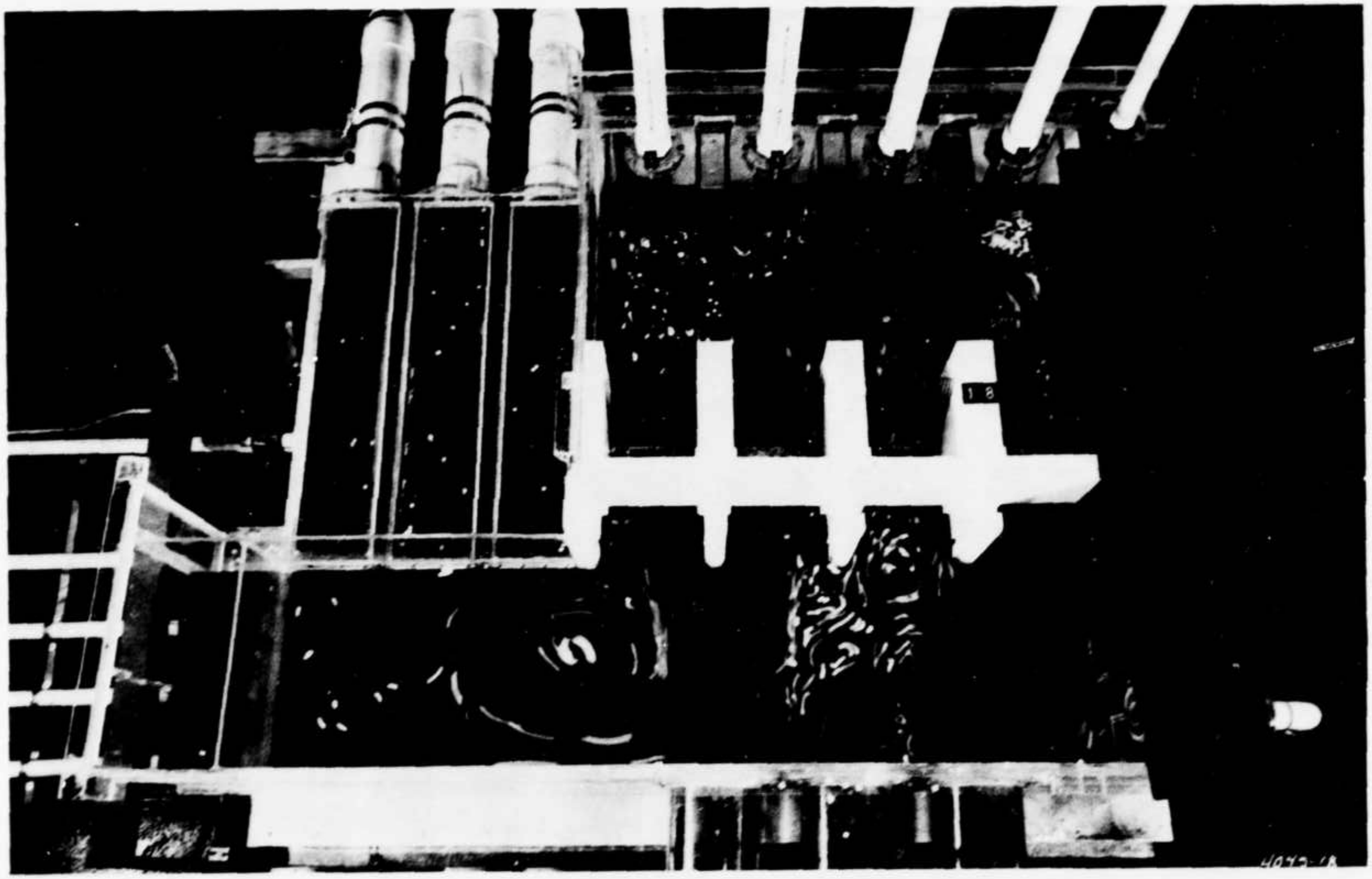


Photo 14. Flow conditions, recommended design; pumps 2, 3, 4, and 5 operating, discharge per pump 34,000 gpm, sump el 757

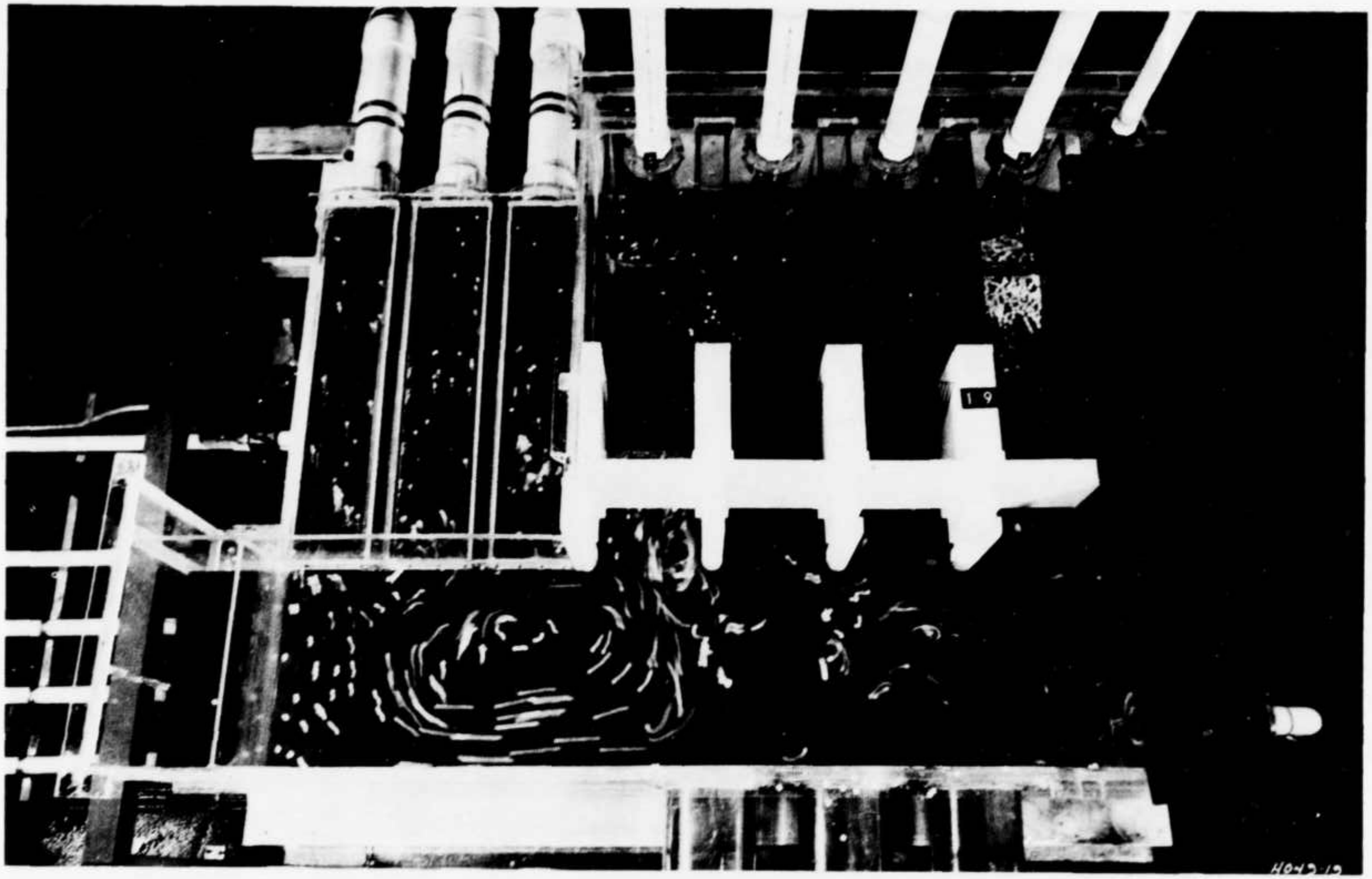


Photo 15. Flow conditions, recommended design; pump 5 operating, discharge 34,000 gpm, sump el 757

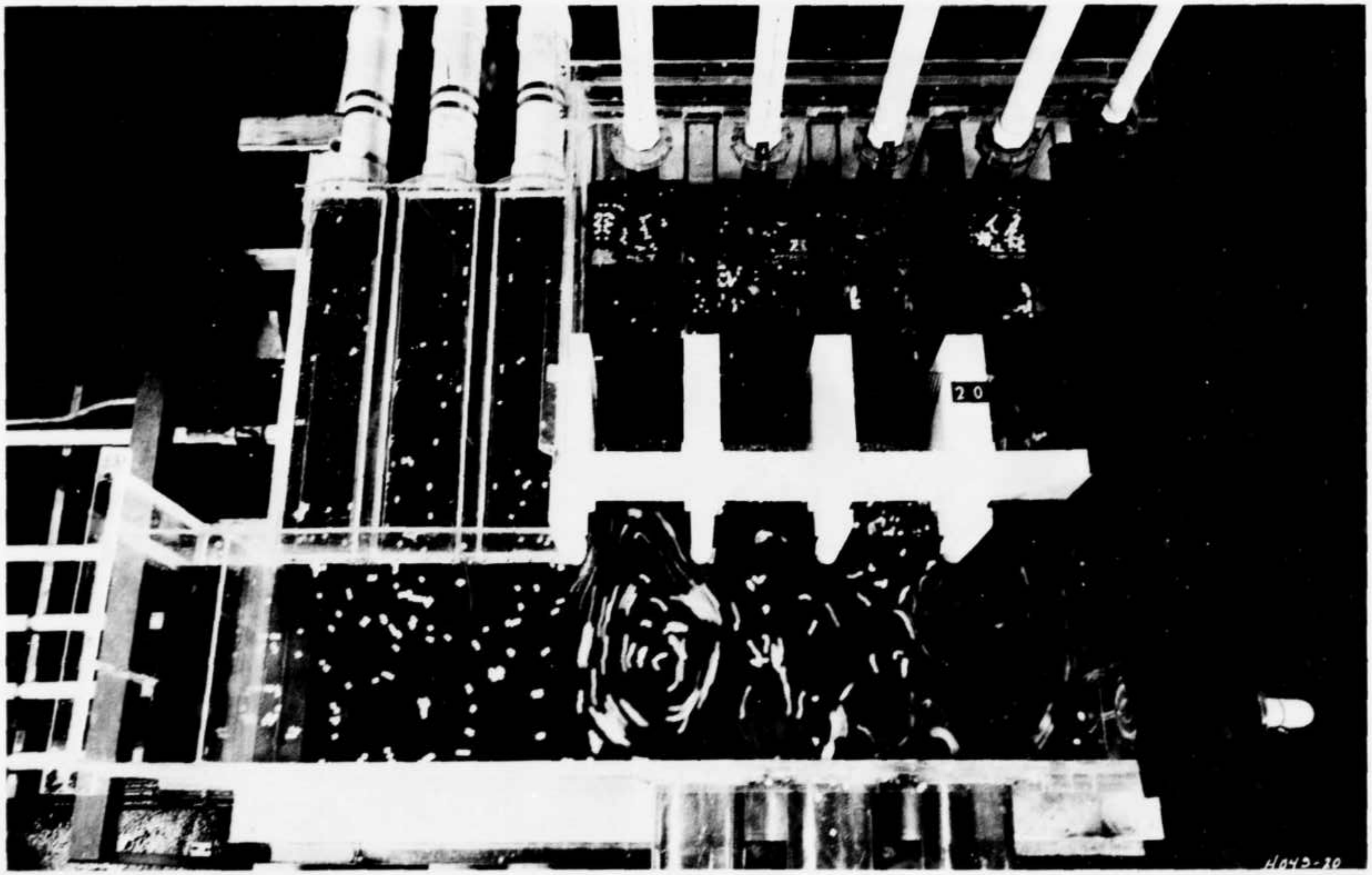


Photo 16. Flow conditions, recommended design; pumps 3 and 4 operating, discharge 34,000 gpm per pump, sump el 797

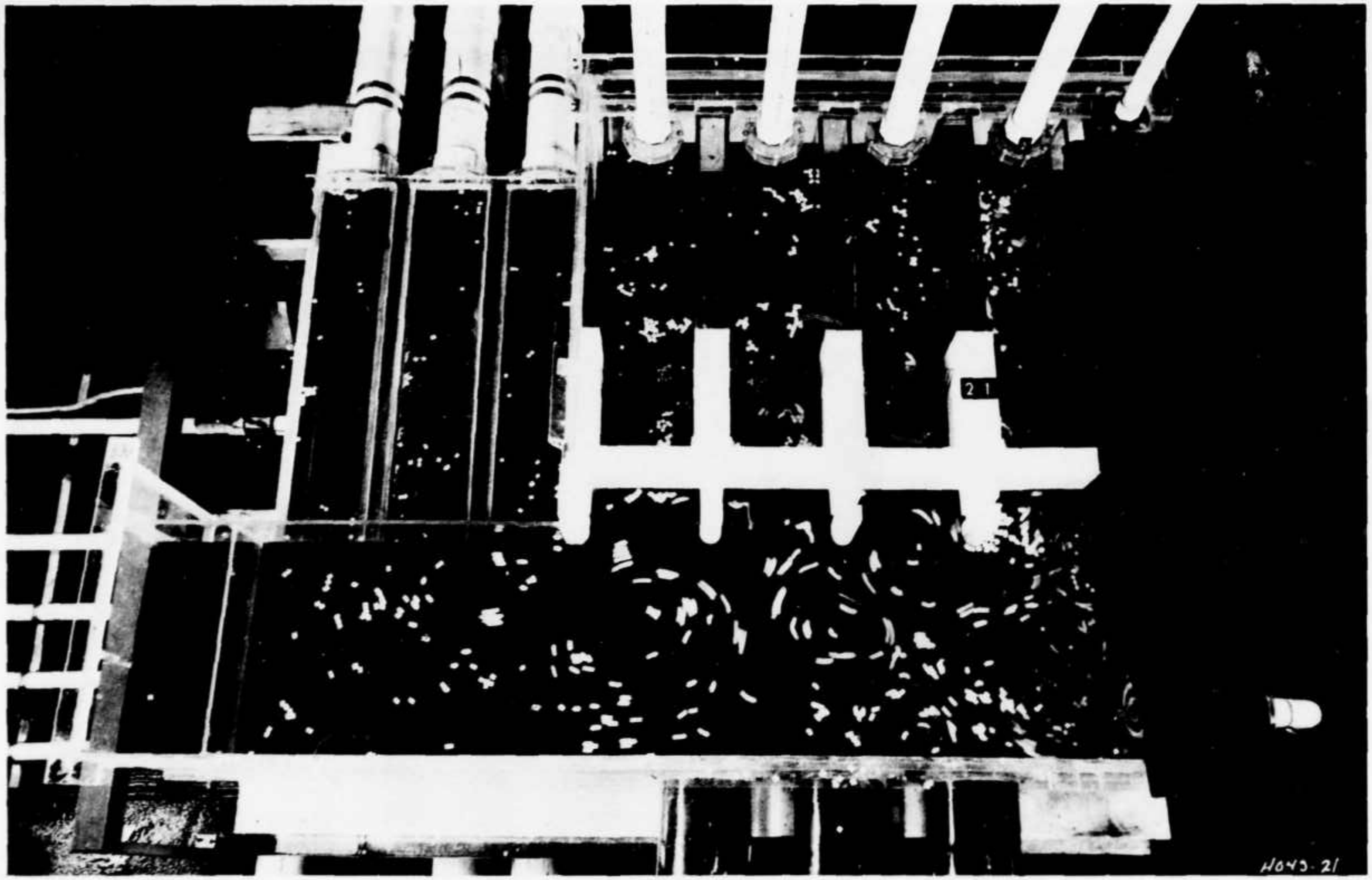


Photo 17. Flow conditions, recommended design; pump 2 operating, discharge 34,000 gpm, sump el 762

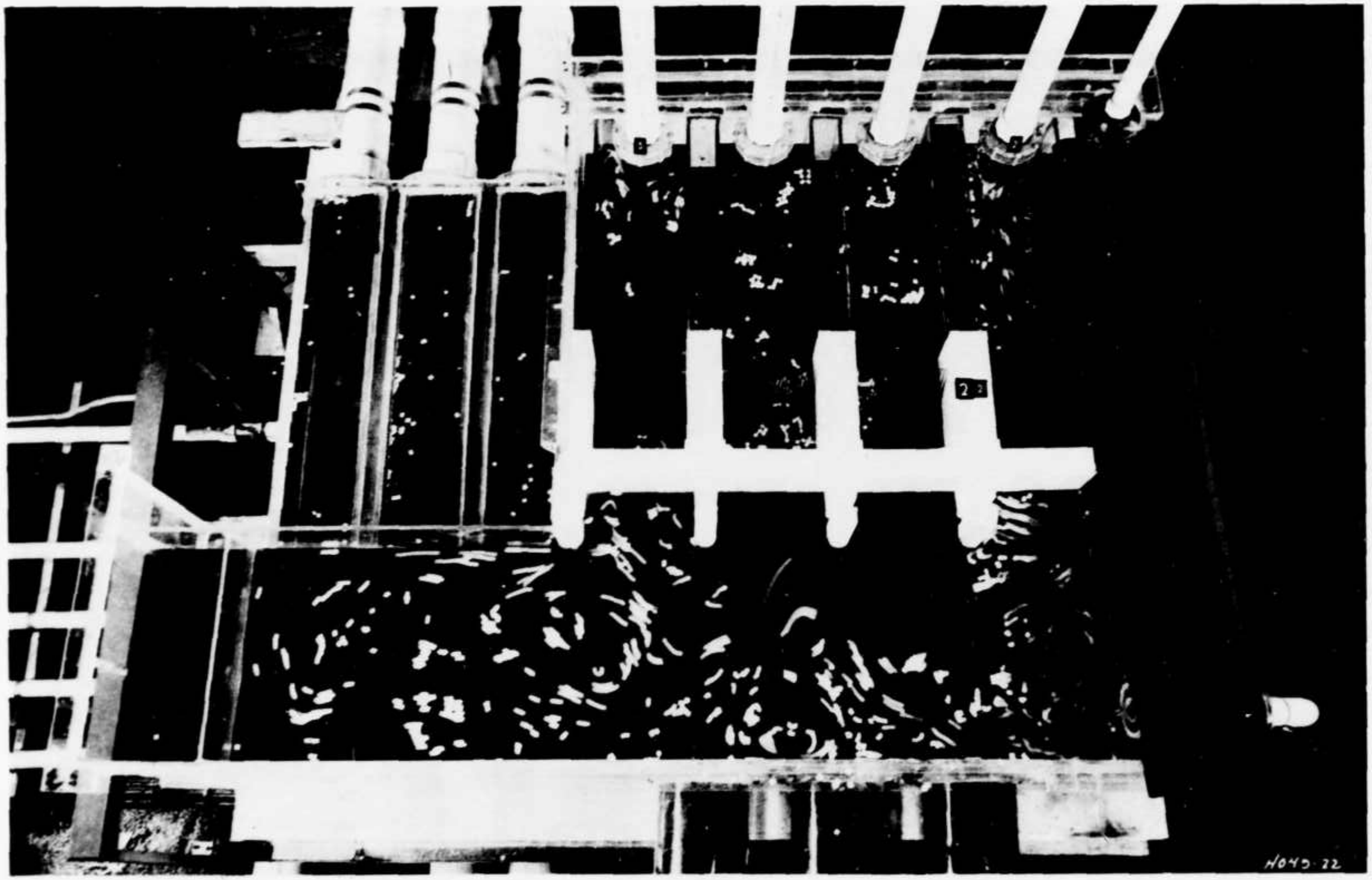


Photo 18. Flow conditions, recommended design; pumps 2 and 5 operating, discharge 34,000 gpm per pump, sump el 762

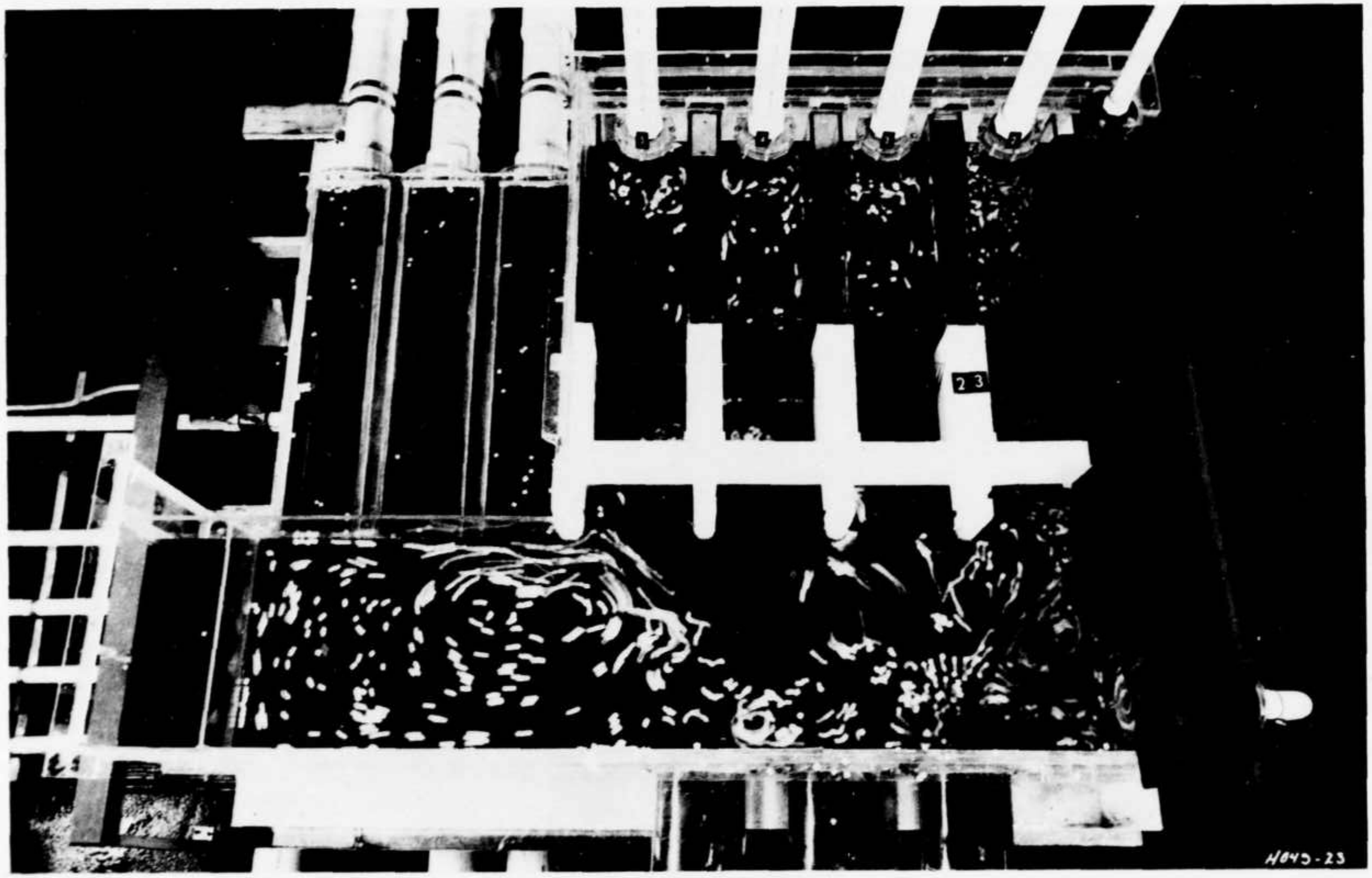


Photo 19. Flow conditions, recommended design; pumps 2, 3, 4, and 5 operating, discharge 34,000 gpm per pump, sump el 762

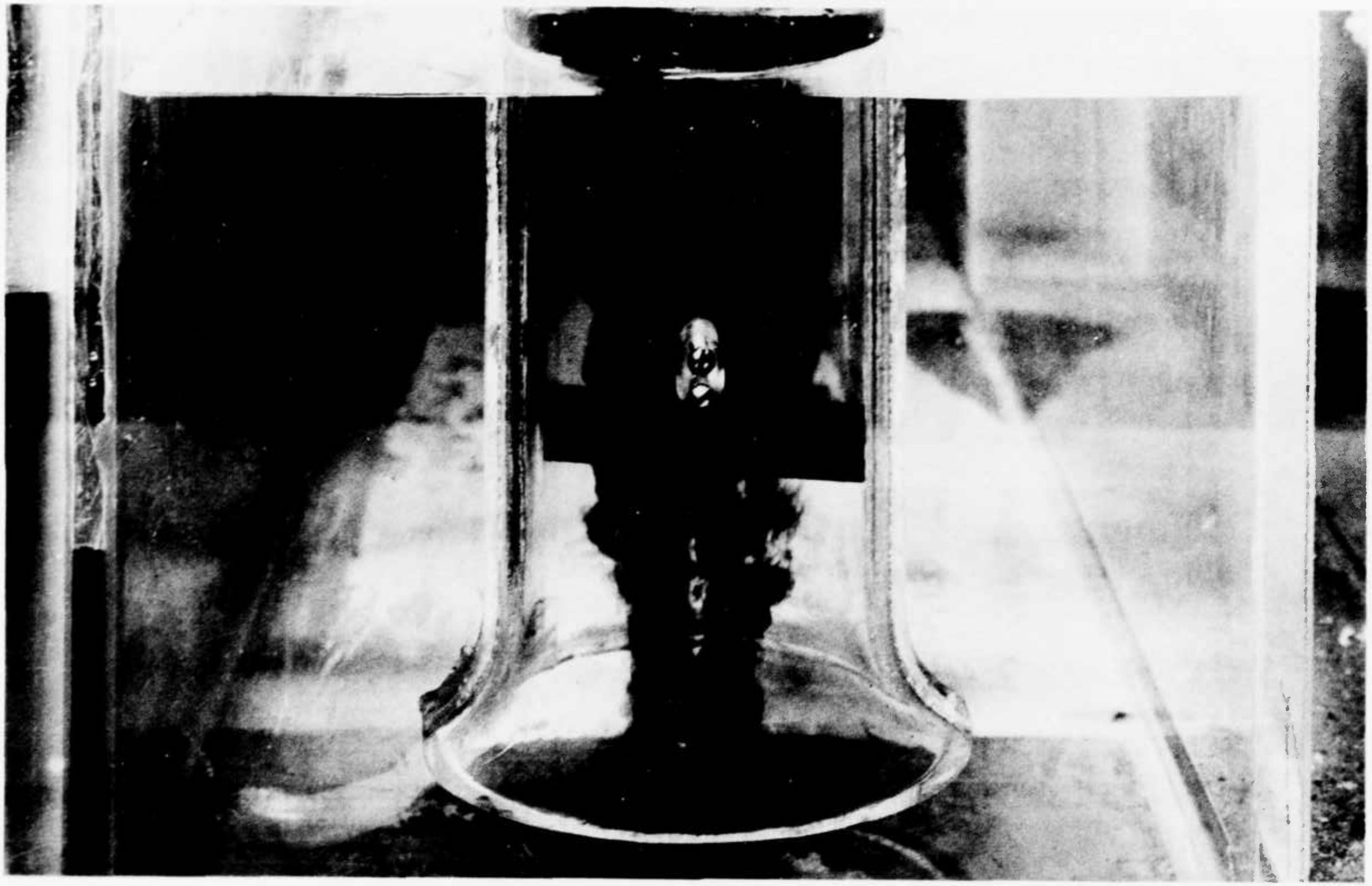


Photo 20. Flow conditions, recommended design; pump 2 operating, discharge 34,000 gpm, sump el 757

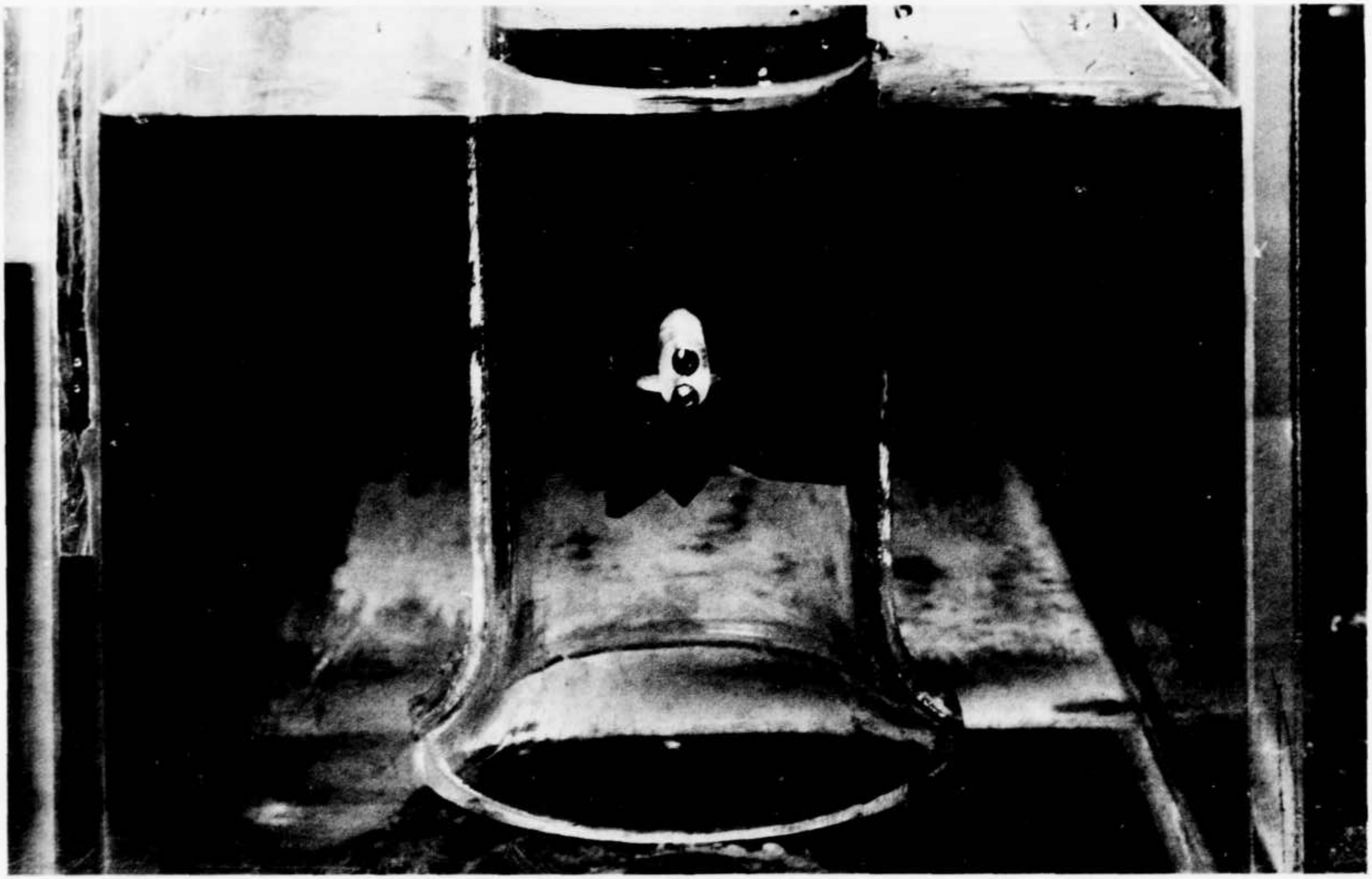


Photo 21. Flow conditions, recommended design; pump 2 operating, discharge 34,000 gpm, sump el 757

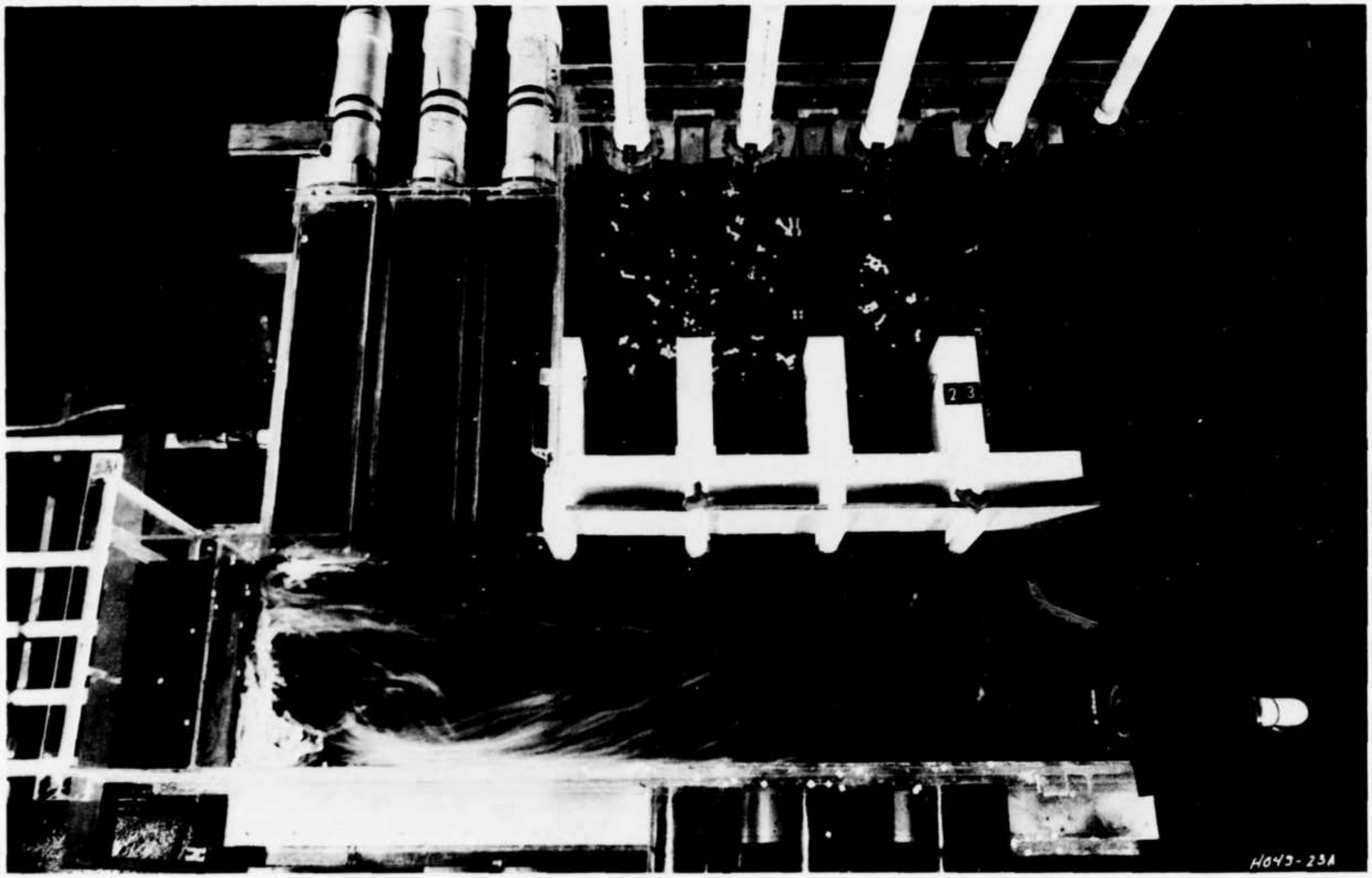


Photo 22. Flow conditions, recommended design; gravity flow, discharge 995 cfs, sump el 761

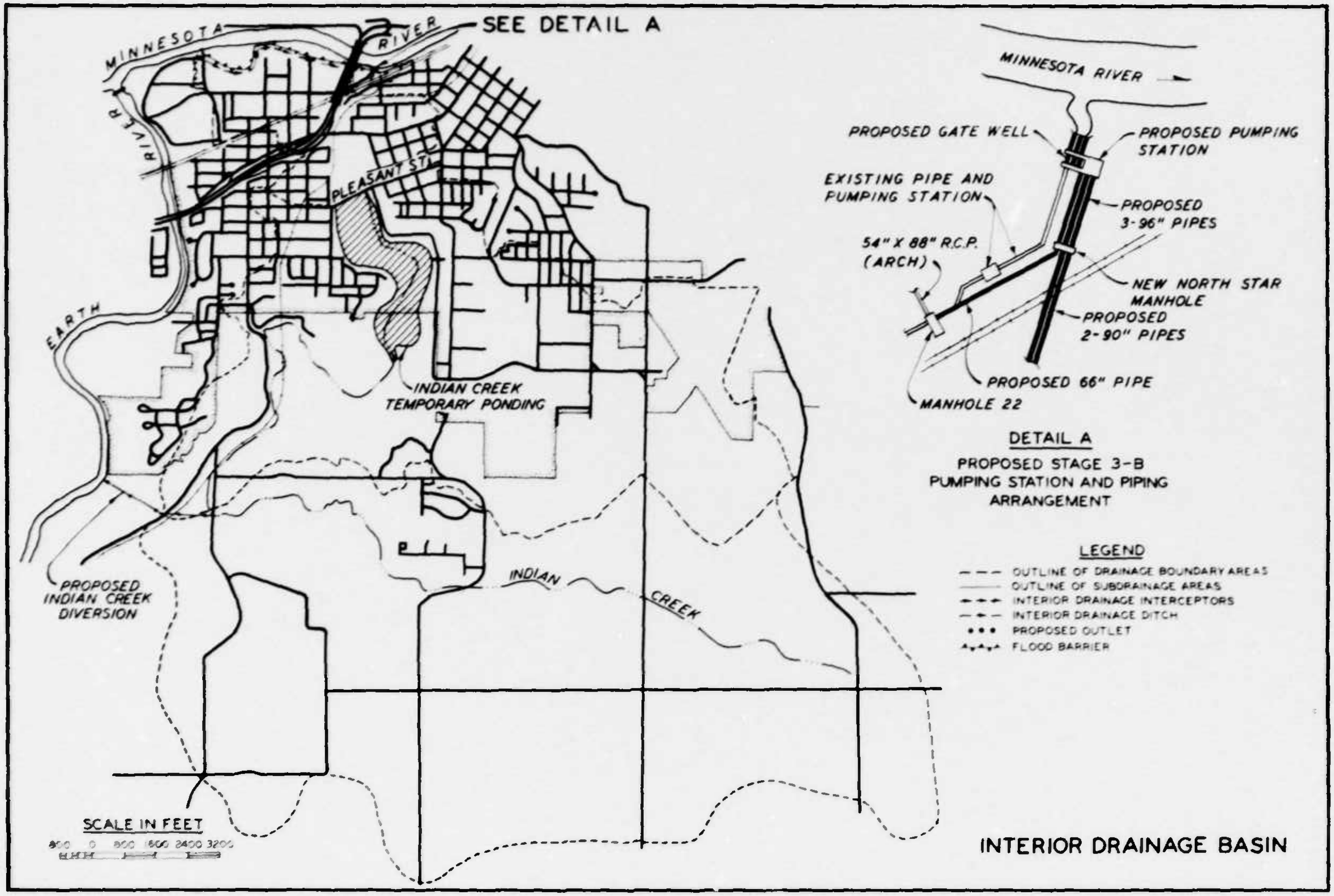
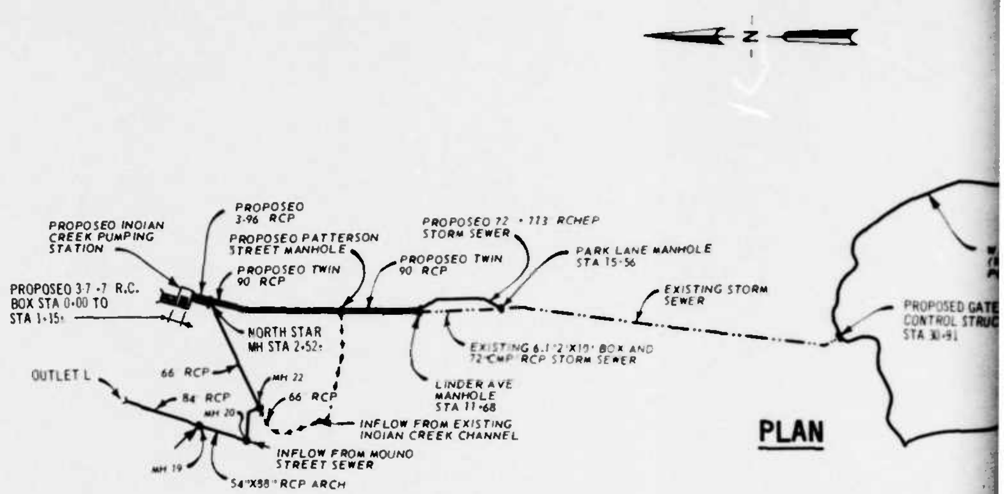
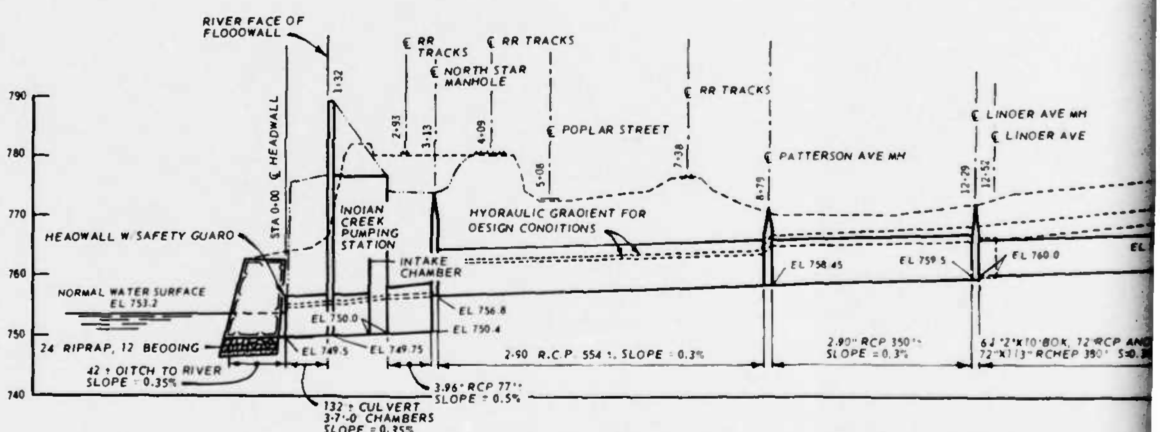

SEE DETAIL A
MINNESOTA RIVER
RIVER
EARTH
PLEASANT ST.
INDIAN CREEK TEMPORARY PONDING
PROPOSED INDIAN CREEK DIVERSION
INDIAN CREEK
SCALE IN FEET
800 0 800 1600 2400 3200
MINNESOTA RIVER
PROPOSED GATE WELL
PROPOSED PUMPING STATION
EXISTING PIPE AND PUMPING STATION
PROPOSED 3-96" PIPES
54" X 88" R.C.P. (ARCH)
NEW NORTH STAR MANHOLE
PROPOSED 2-90" PIPES
PROPOSED 66" PIPE
MANHOLE 22
DETAIL A
PROPOSED STAGE 3-B PUMPING STATION AND PIPING ARRANGEMENT
LEGEND
OUTLINE OF DRAINAGE BOUNDARY AREAS
OUTLINE OF SUBDRAINAGE AREAS
INTERIOR DRAINAGE INTERCEPTORS
INTERIOR DRAINAGE DITCH
PROPOSED OUTLET
FLOOD BARRIER
INTERIOR DRAINAGE BASIN

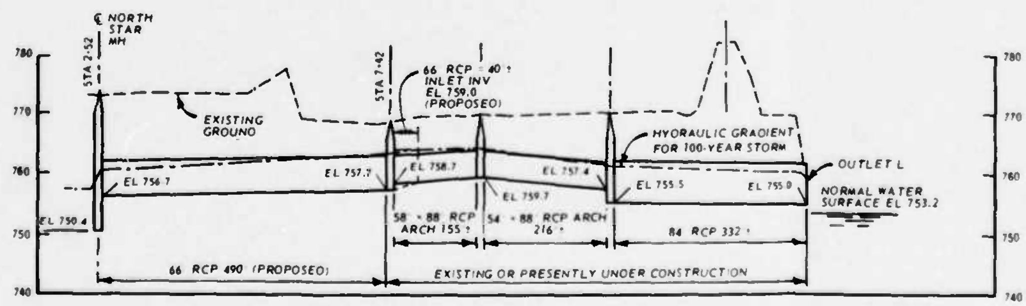
PLATE 1



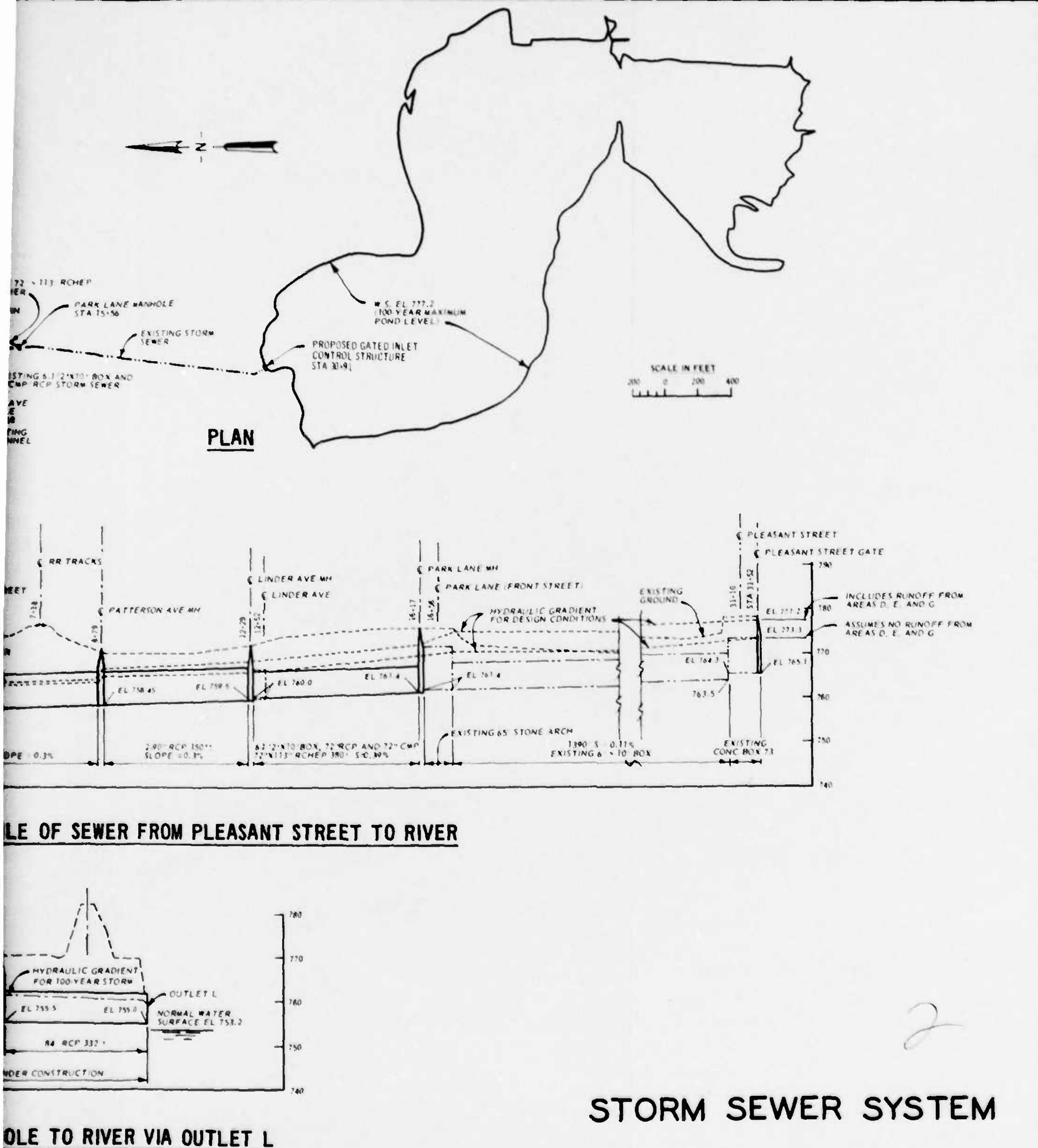
PLAN



PROFILE OF SEWER FROM PLEASANT STREET T

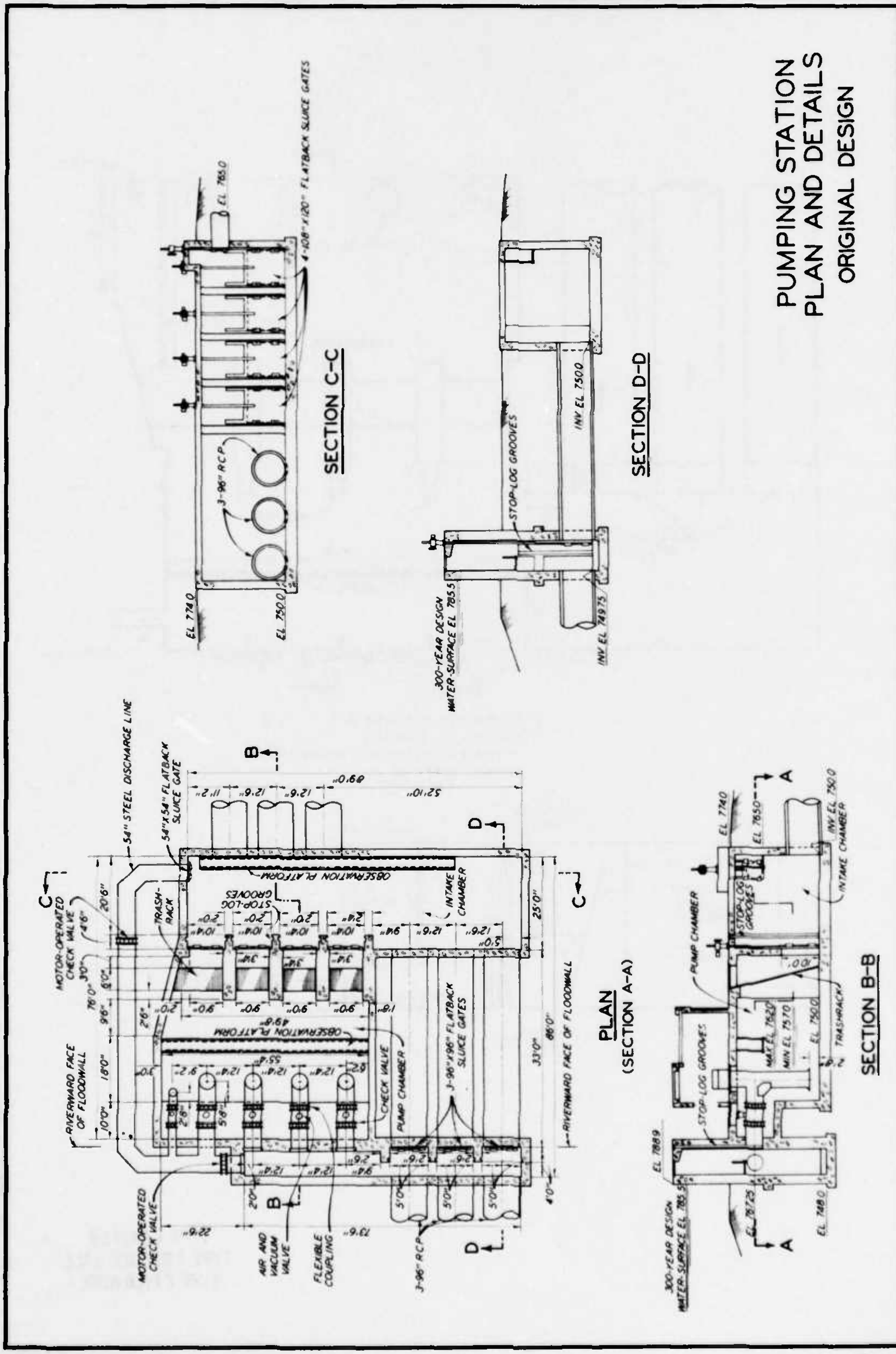


PROFILE OF SEWER FROM NORTH STAR MANHOLE TO RIVER VIA OUTLET L

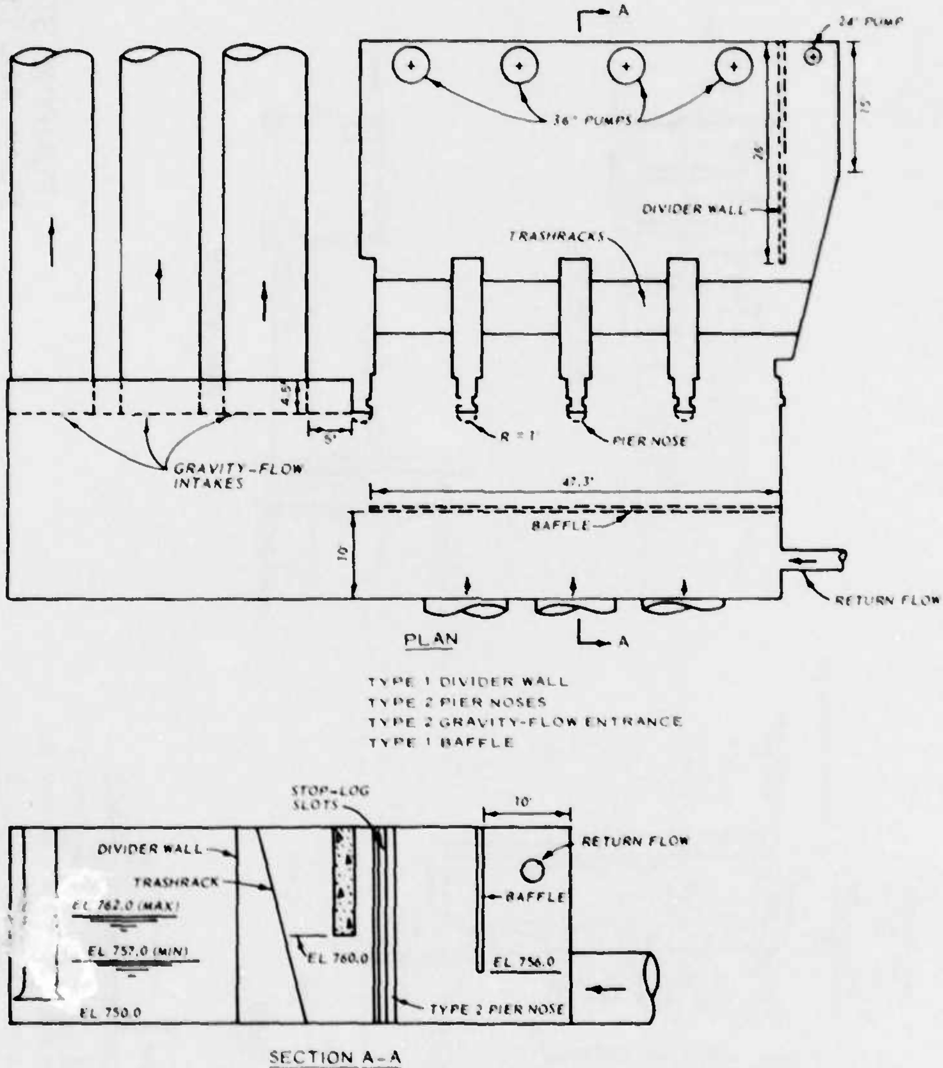


STORM SEWER SYSTEM

PLATE 2

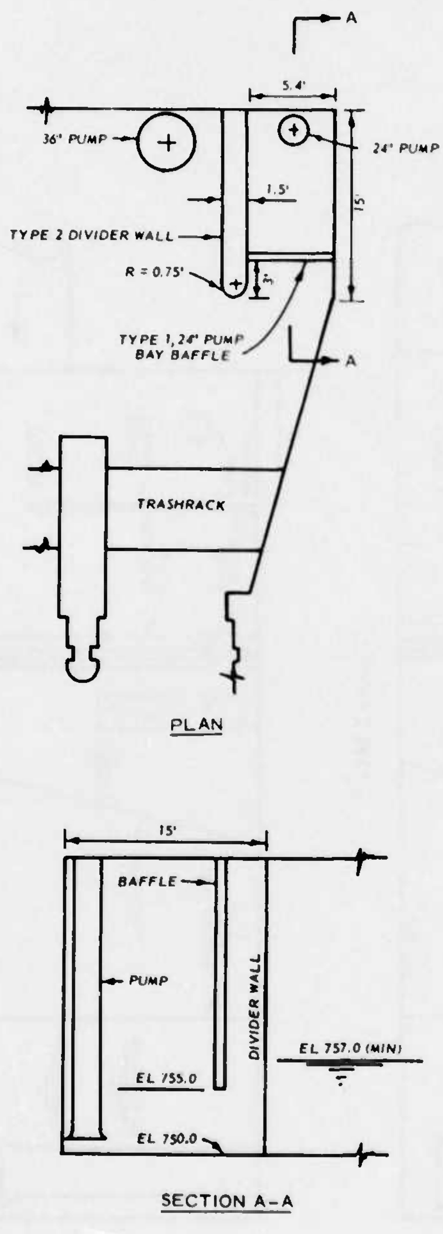


PUMPING STATION
PLAN AND DETAILS
ORIGINAL DESIGN
SECTION C-C
3-96" RCP
4-108"x120" FLATBACK SLUICE GATES
EL 774.0
EL 750.0
EL 785.0
SECTION D-D
STOP-LOG GROOVES
INV EL 750.0
INV EL 749.75
300-YEAR DESIGN WATER-SURFACE EL 785.5
PLAN
(SECTION A-A)
54" STEEL DISCHARGE LINE
54"x54" FLATBACK SLUICE GATE
MOTOR-OPERATED CHECK VALVE
TRASH-RACK
RIVERWARD FACE OF FLOODWALL
OBSERVATION PLATFORM
STOP-LOG GROOVES
INTAKE CHAMBER
CHECK VALVE
PUMP CHAMBER
3-96"x96" FLATBACK SLUICE GATES
AIR AND VACUUM VALVE
FLEXIBLE COUPLING
3-96" RCP
SECTION B-B
PUMP CHAMBER
INTAKE CHAMBER
TRASHRACK
STOP-LOG GROOVES
EL 788.9
EL 787.25
EL 748.0
EL 774.0
EL 785.0
INV EL 750.0
MAX EL 762.0
MIN EL 757.0
EL 750.0
300-YEAR DESIGN WATER-SURFACE EL 785.5

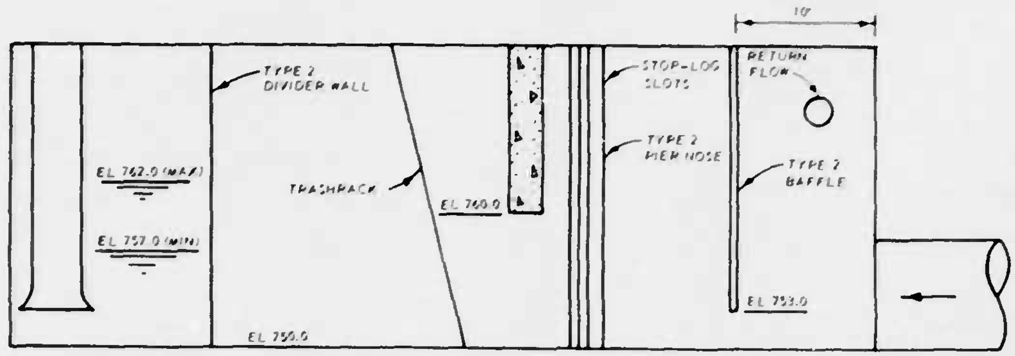


TYPE 1 BAFFLE
TYPE 1 DIVIDER WALL
TYPE 2 PIER NOSE

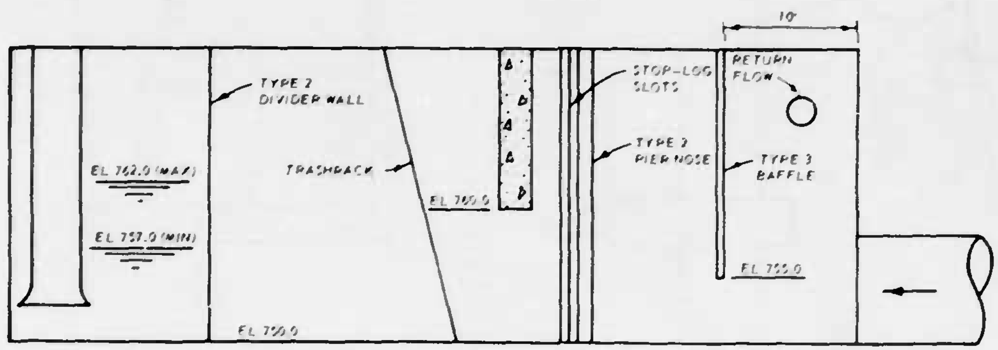
PLATE 4



TYPE 2 DIVIDER WALL
TYPE 1, 24-IN. PUMP BAY BAFFLE

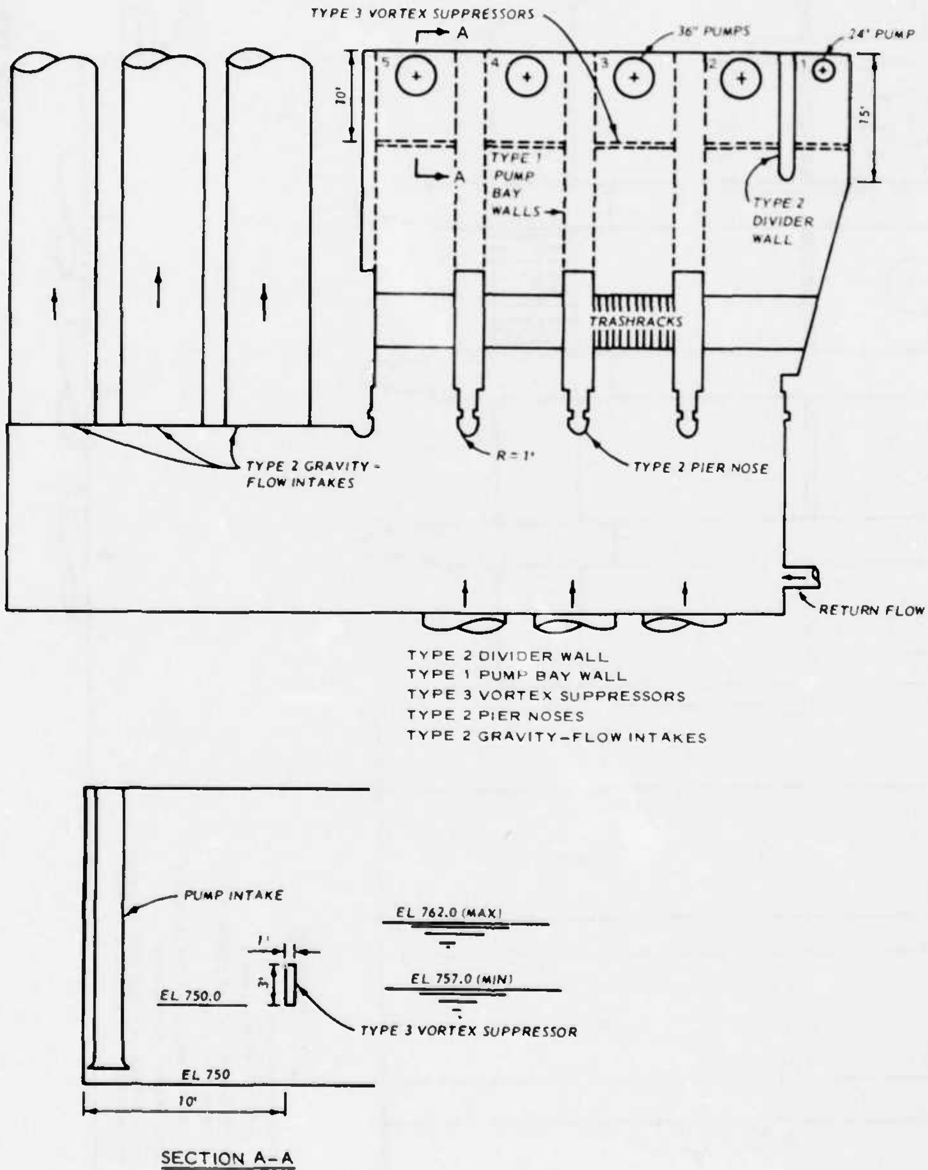


a. TYPE 2 BAFFLE



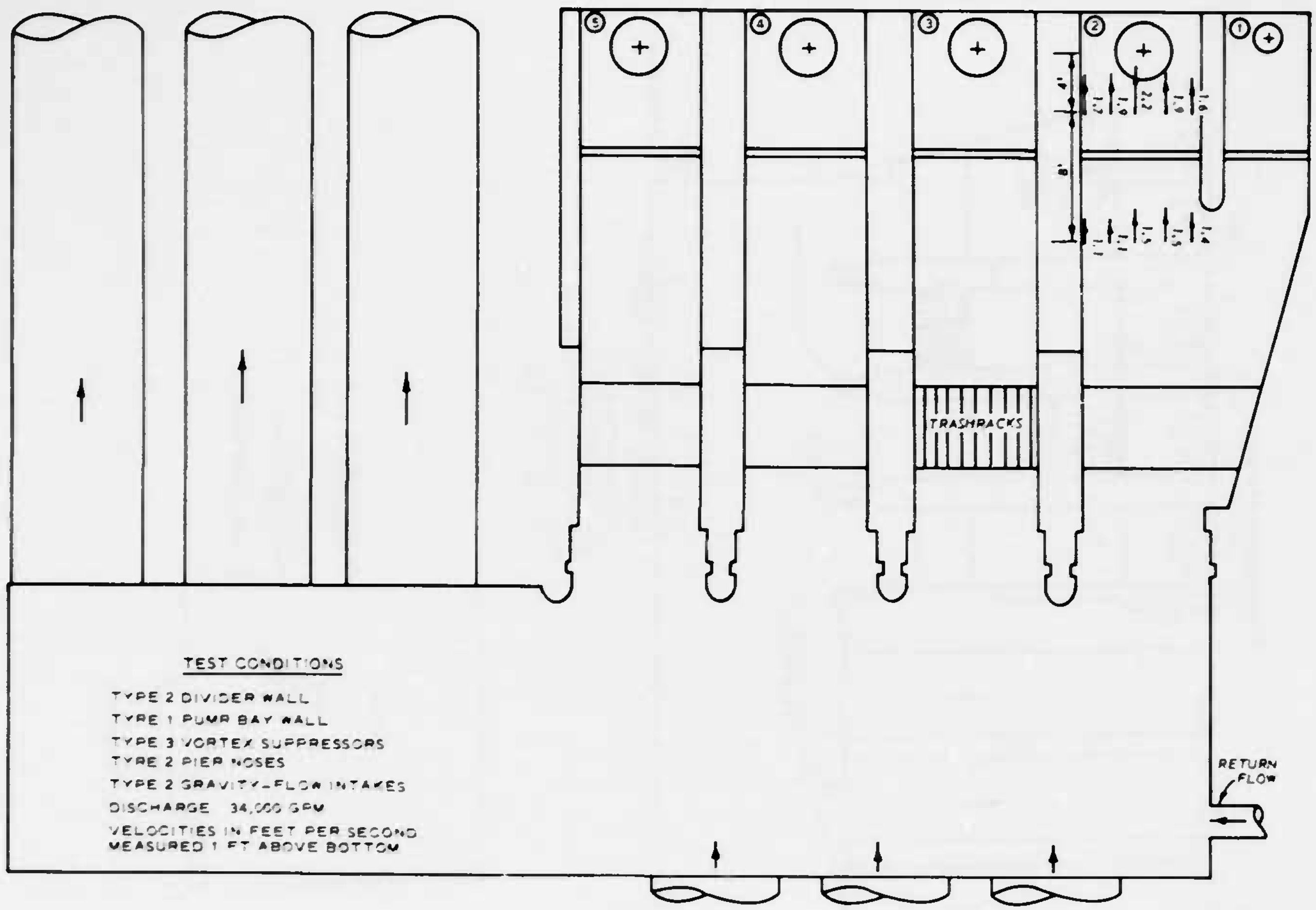
b. TYPE 3 BAFFLE

TYPES 2 AND 3 BAFFLES
TYPE 2 DIVIDER WALL (24-IN. PUMP)
TYPE 2 PIER NOSE

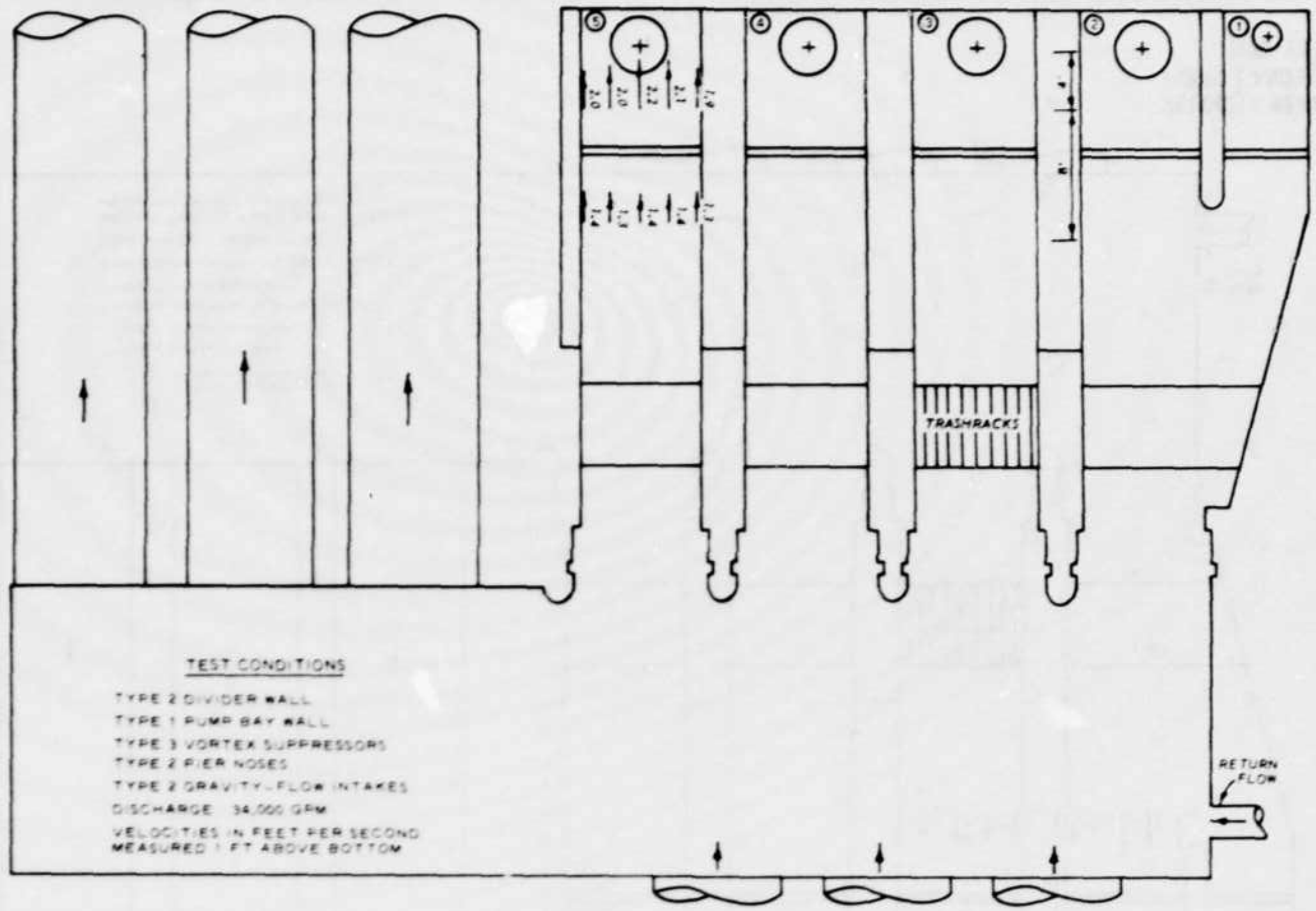


TYPE 3 VORTEX SUPPRESSORS

PLATE 8

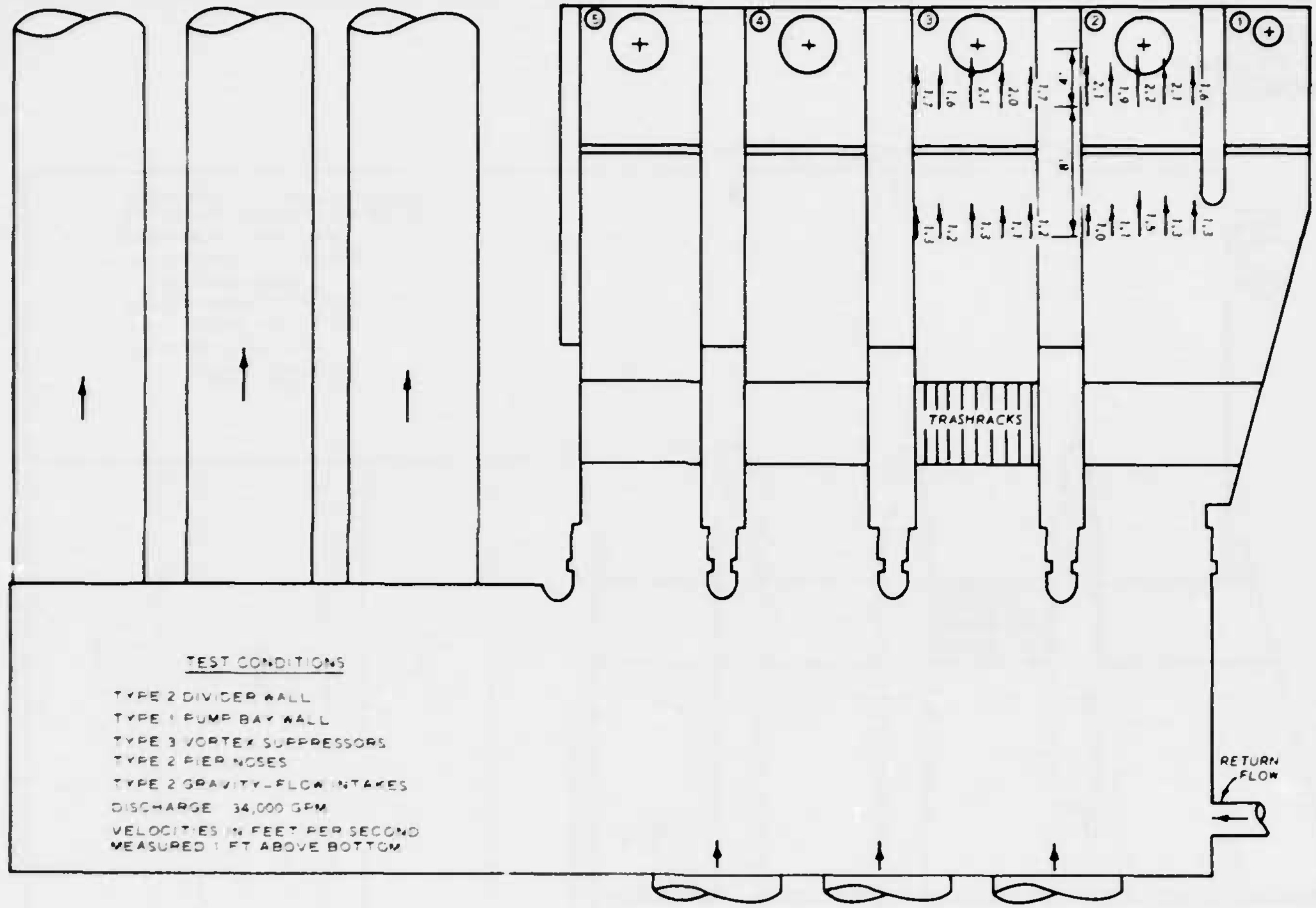


VELOCITY MEASUREMENTS
PUMP 2 OPERATING
SUMP EL 757



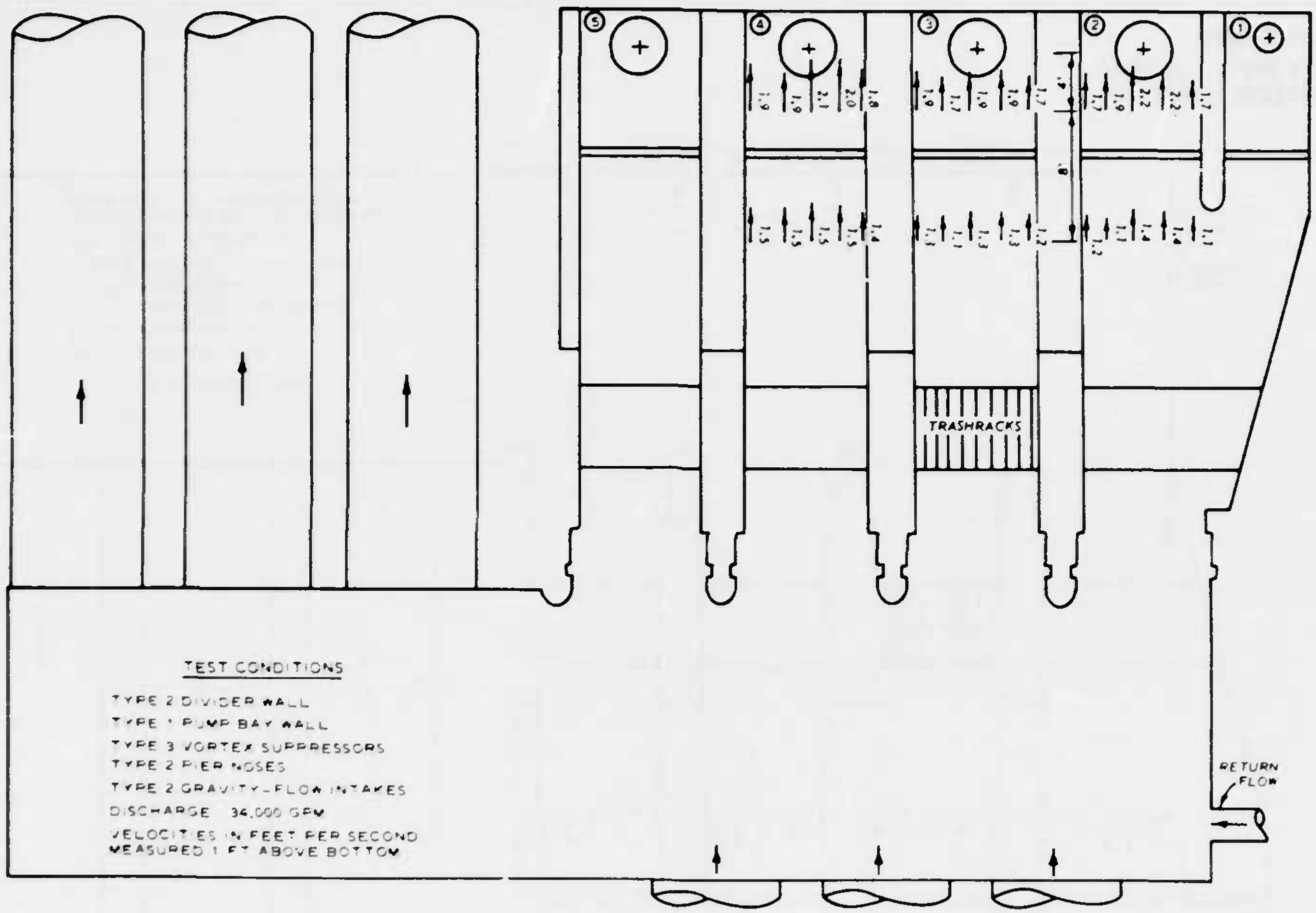
VELOCITY MEASUREMENTS
PUMP 5 OPERATING
SUMP EL 757

PLATE 9

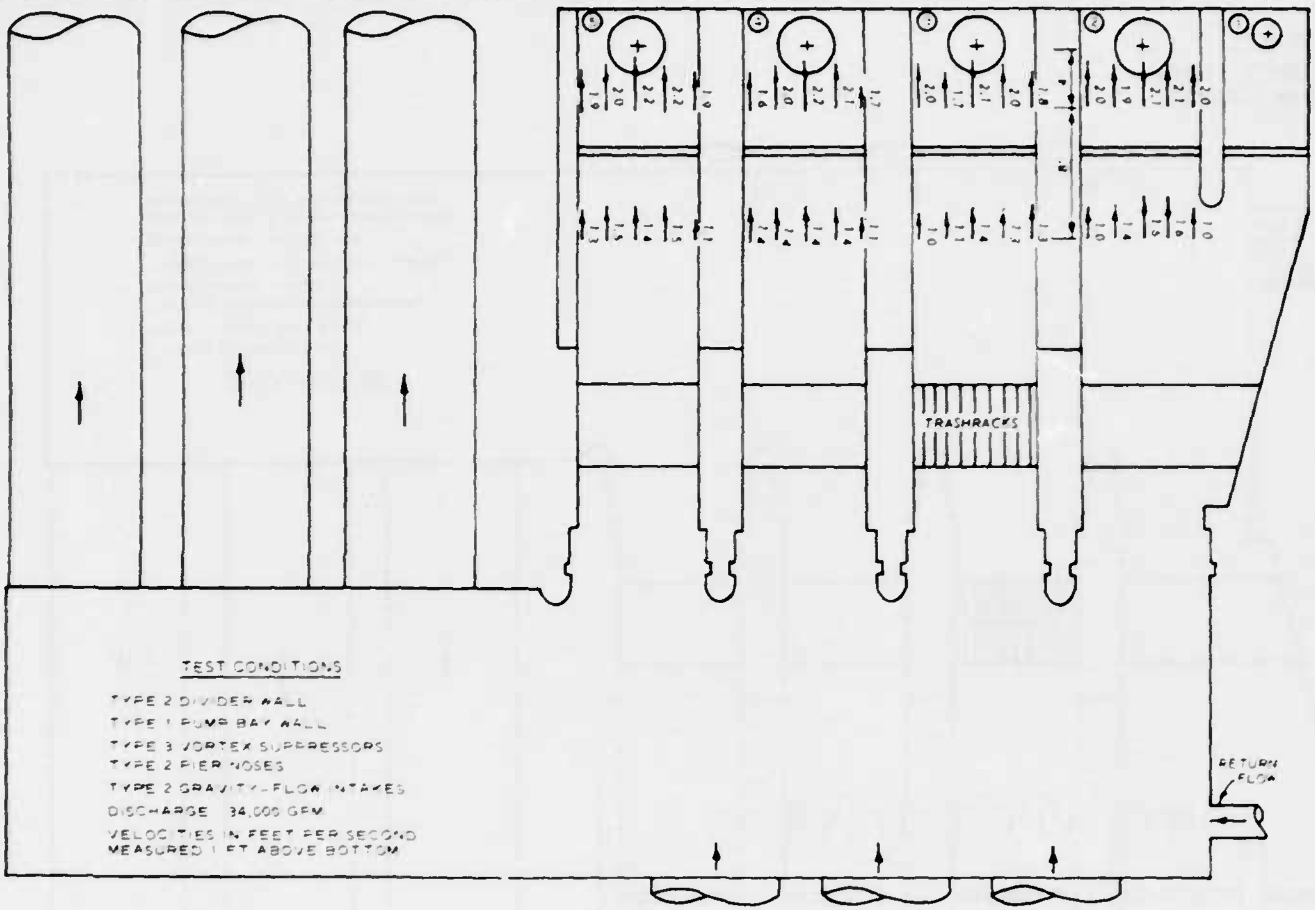


VELOCITY MEASUREMENTS
PUMPS 2 AND 3 OPERATING
SUMP EL 757

PLATE 10

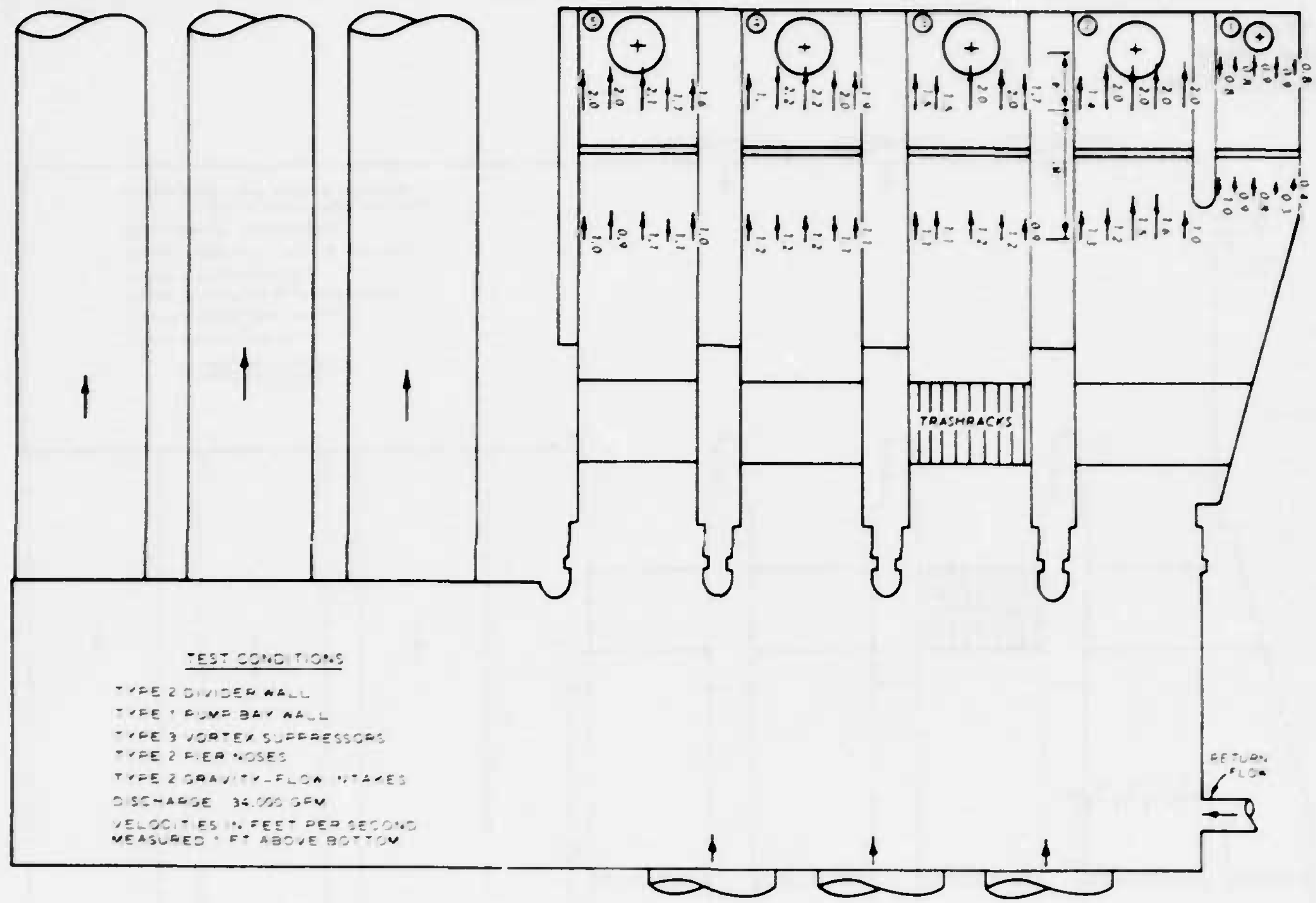


VELOCITY MEASUREMENTS
PUMPS 2, 3, AND 4 OPERATING
SUMP EL 757

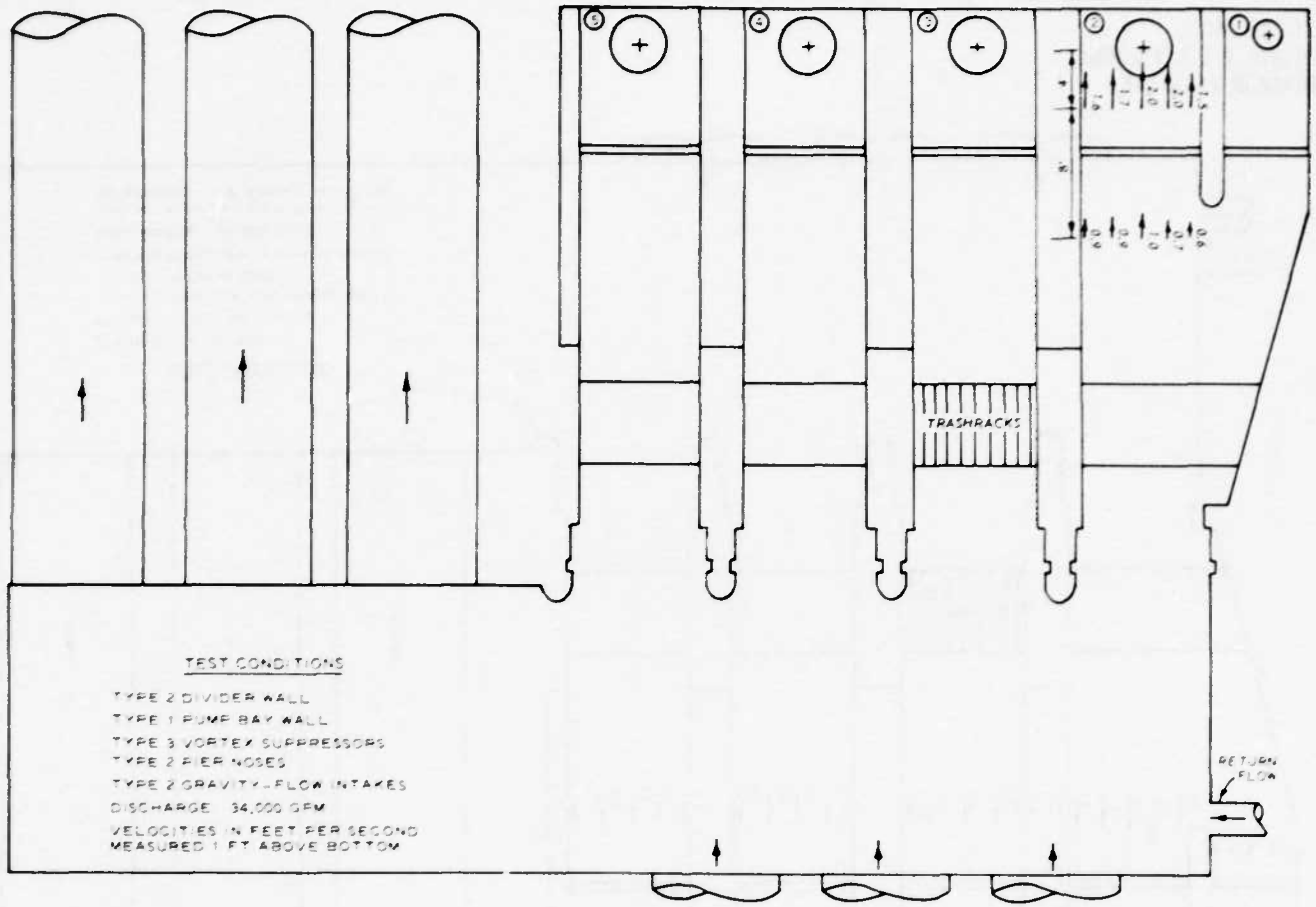


VELOCITY MEASUREMENTS
PUMPS 2, 3, 4, AND 5 OPERATING
SUMP EL 757

PLATE 12

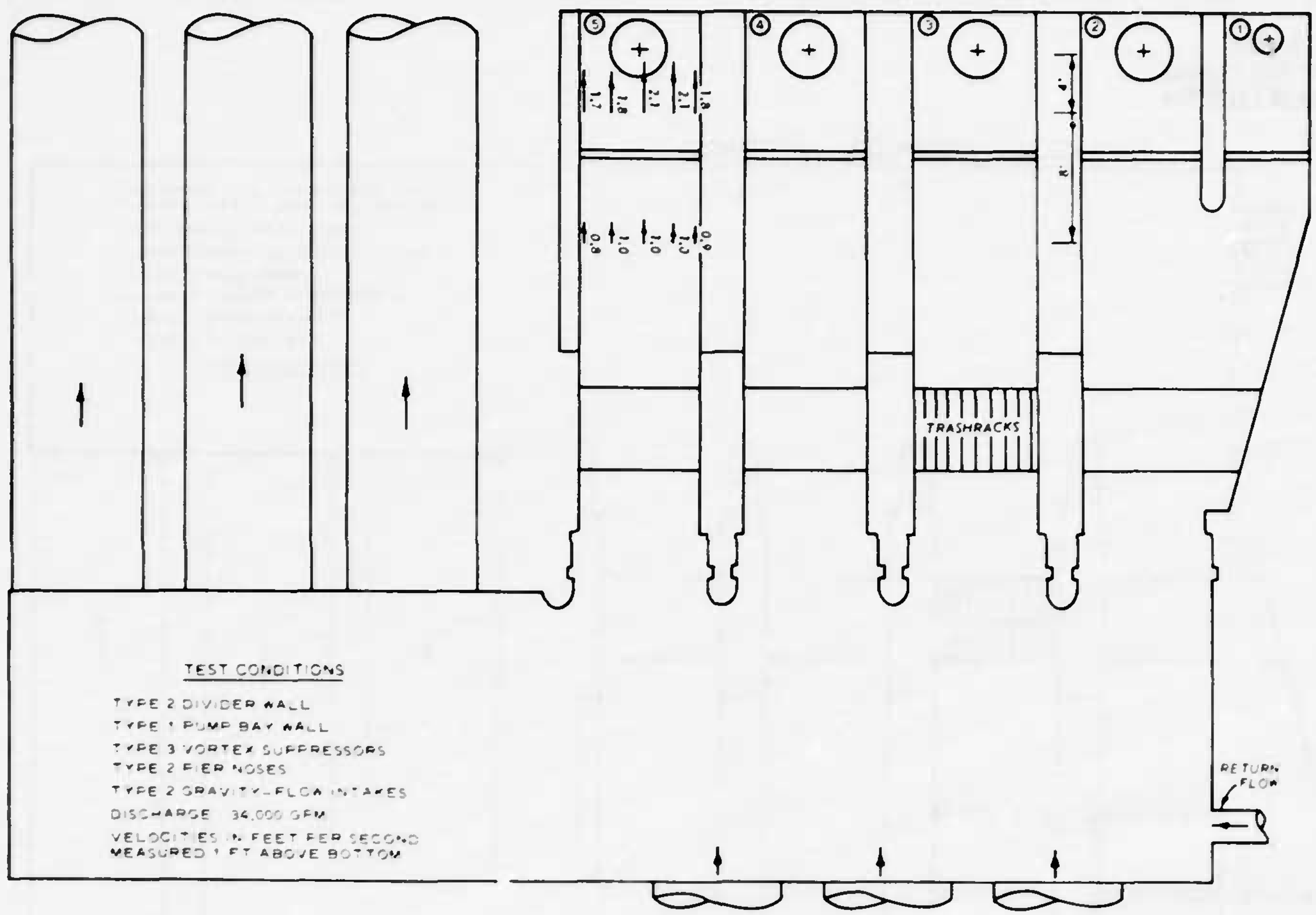


VELOCITY MEASUREMENTS
PUMPS 1, 2, 3, 4, AND 5 OPERATING
SUMP EL 757



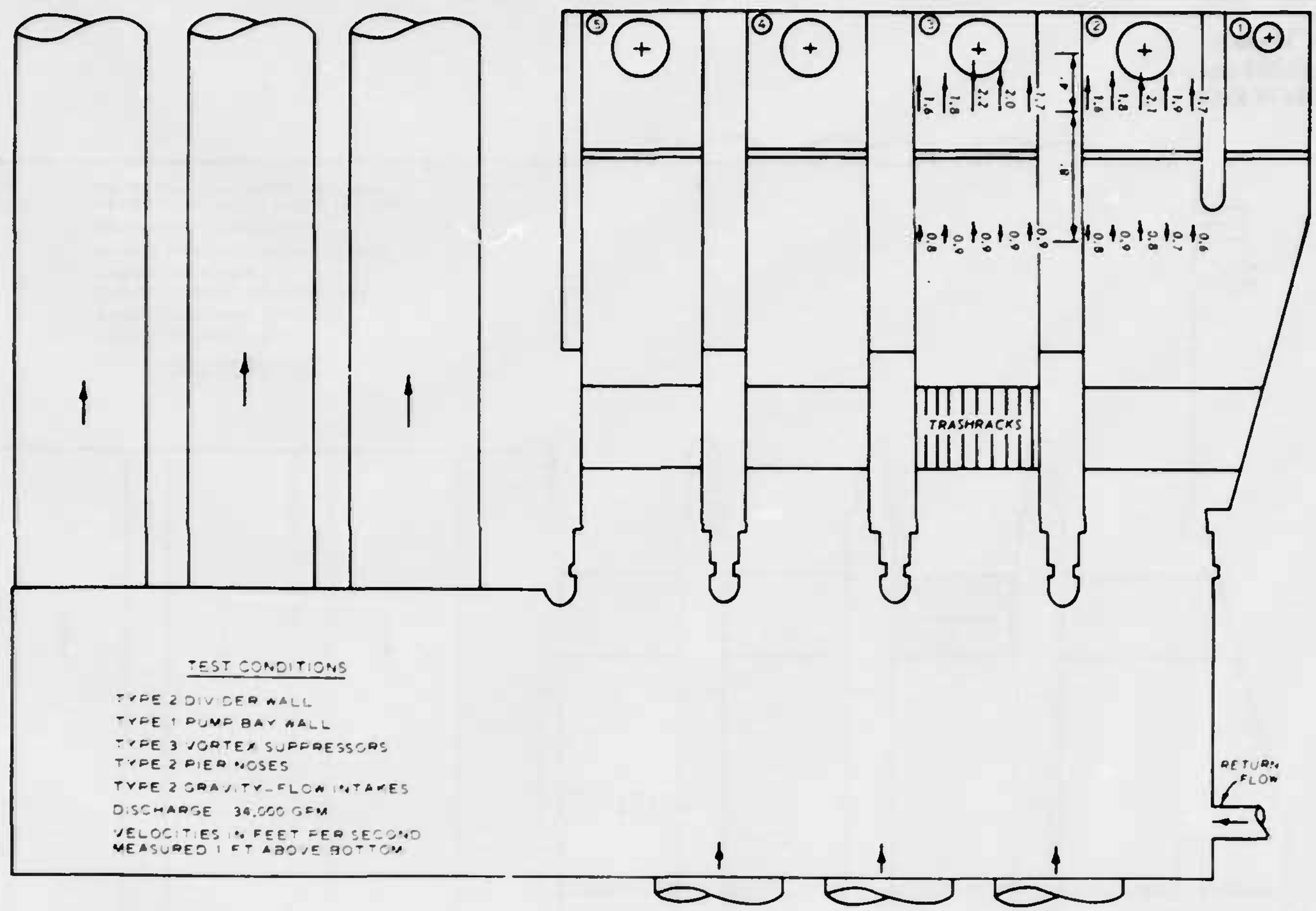
VELOCITY MEASUREMENTS
PUMP 2 OPERATING
SUMP EL 760

PLATE 14

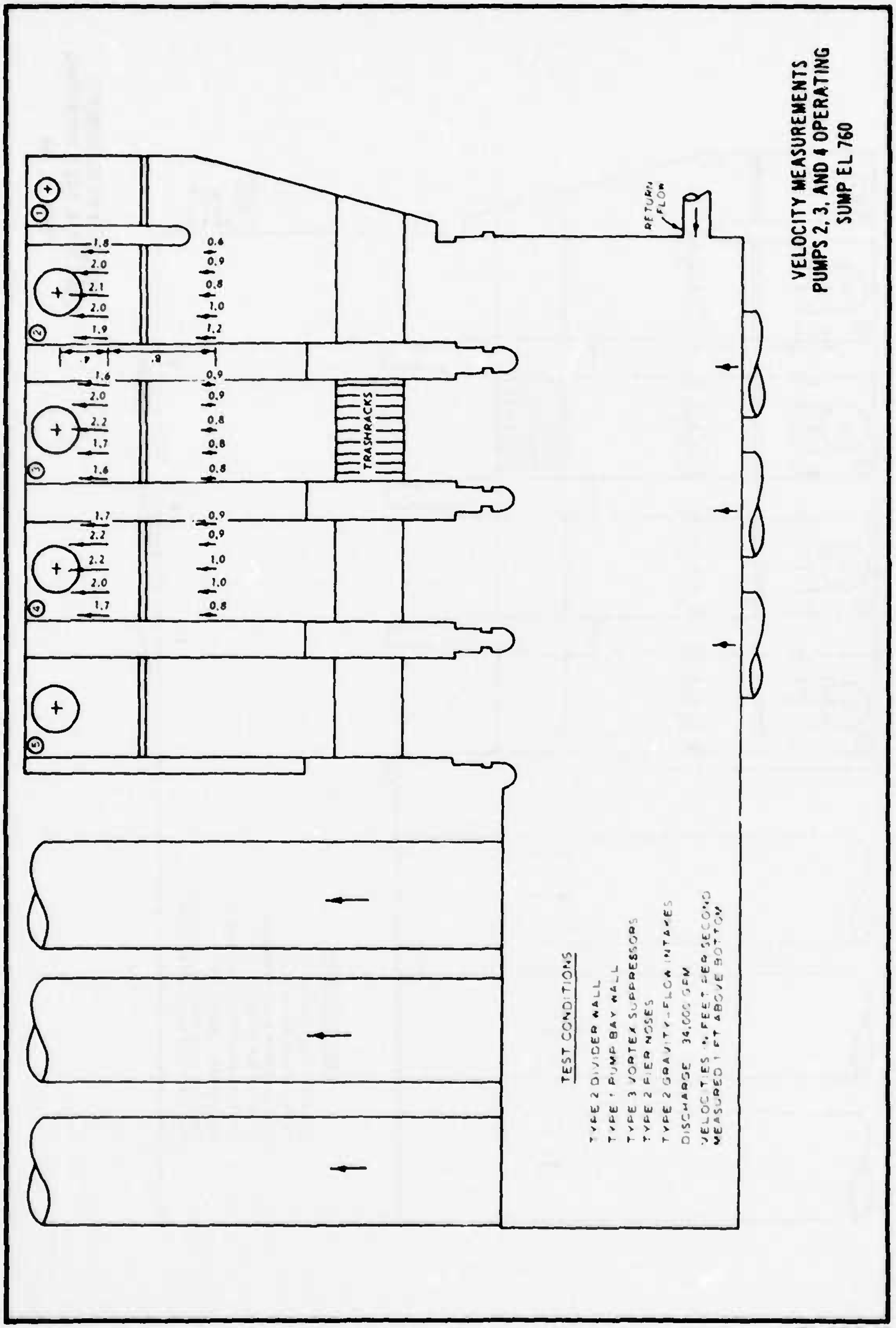


VELOCITY MEASUREMENTS
PUMP 5 OPERATING
SUMP EL 760

PLATE 16

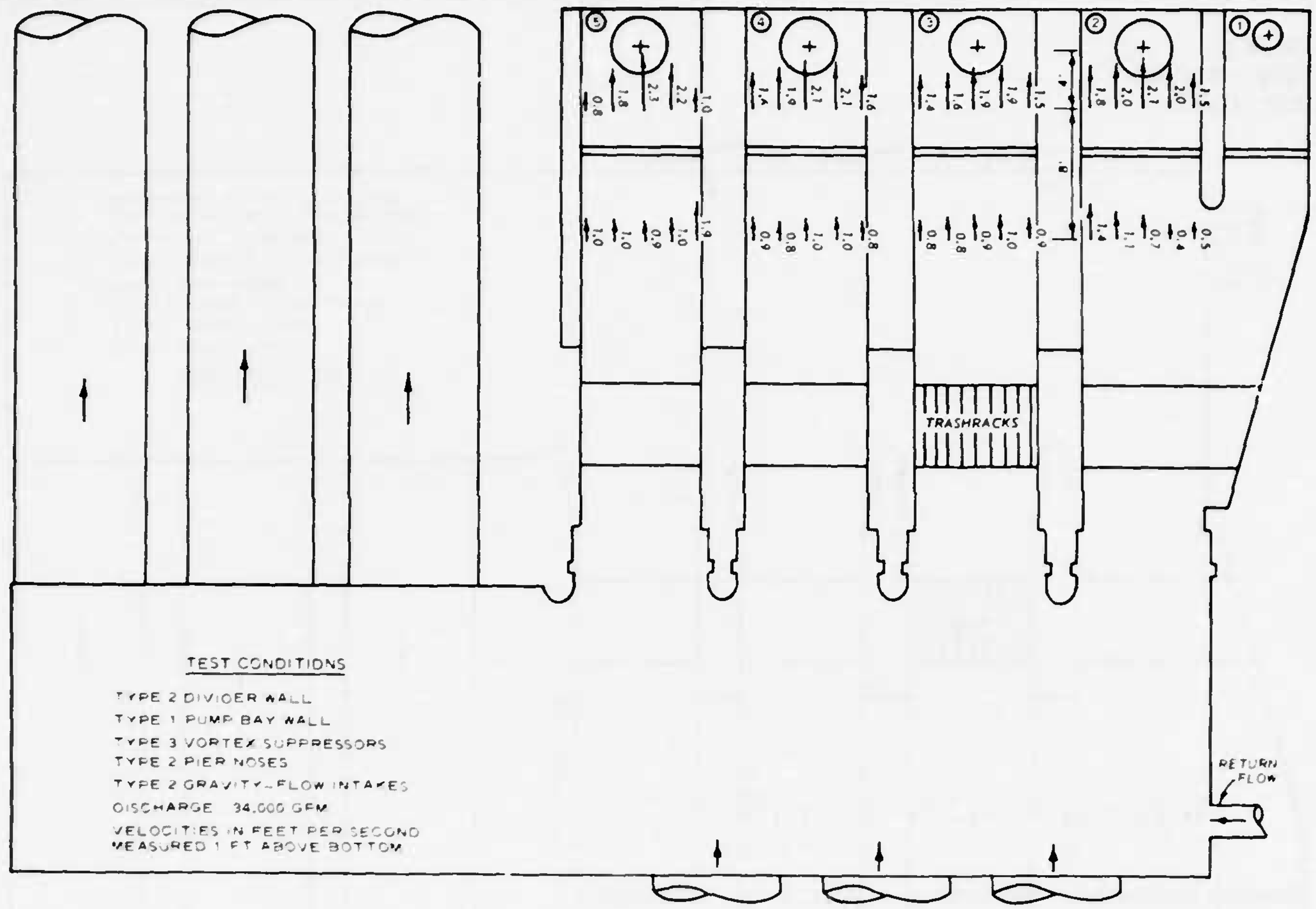


VELOCITY MEASUREMENTS
PUMPS 2 AND 3 OPERATING
SUMP EL 760



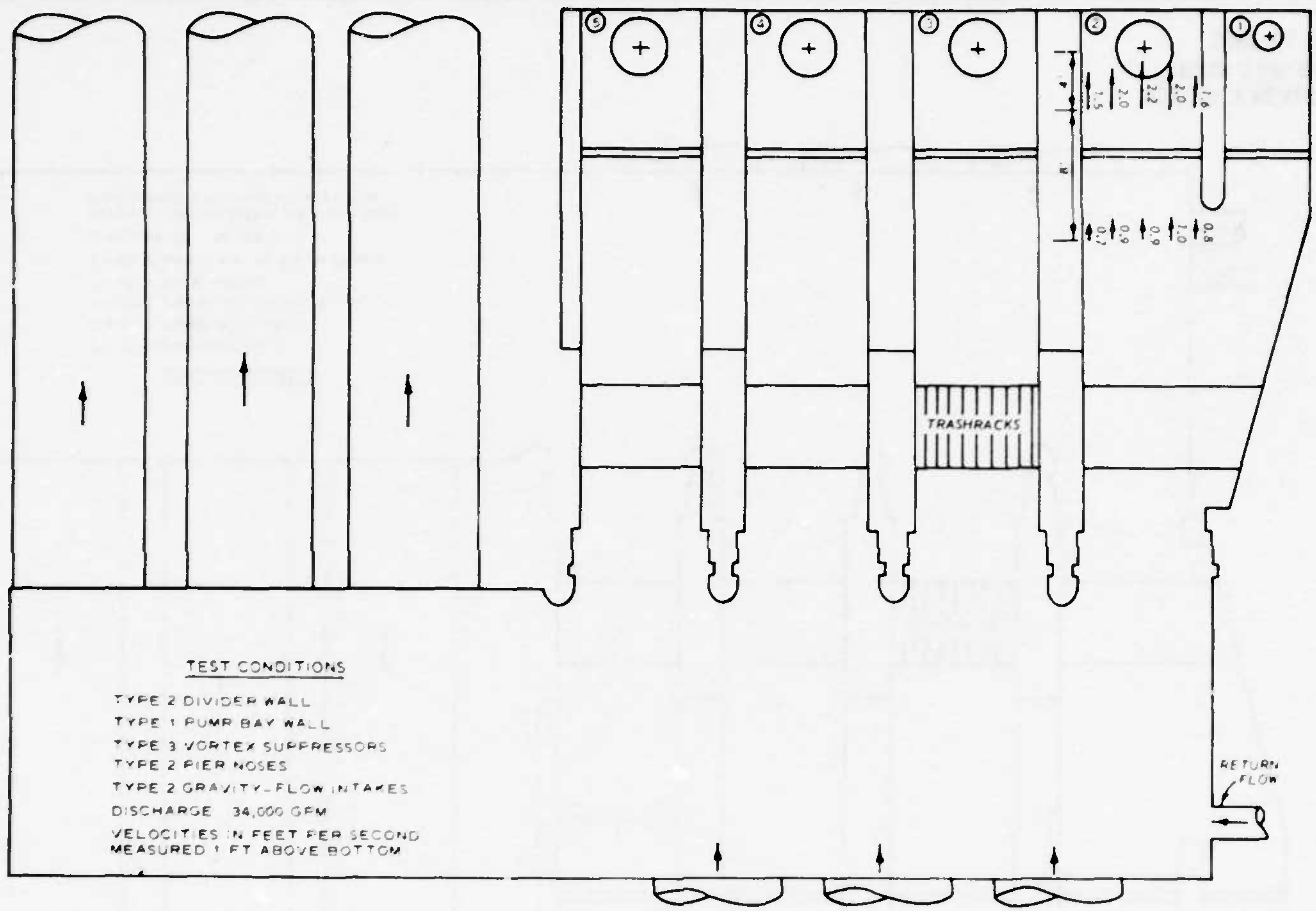
VELOCITY MEASUREMENTS
PUMPS 2, 3, AND 4 OPERATING
SUMP EL 760

PLATE 17



VELOCITY MEASUREMENTS
PUMPS 2, 3, 4, AND 5 OPERATING
SUMP EL 760

PLATE 18



VELOCITY MEASUREMENTS
PUMP 2 OPERATING
SUMP EL 761

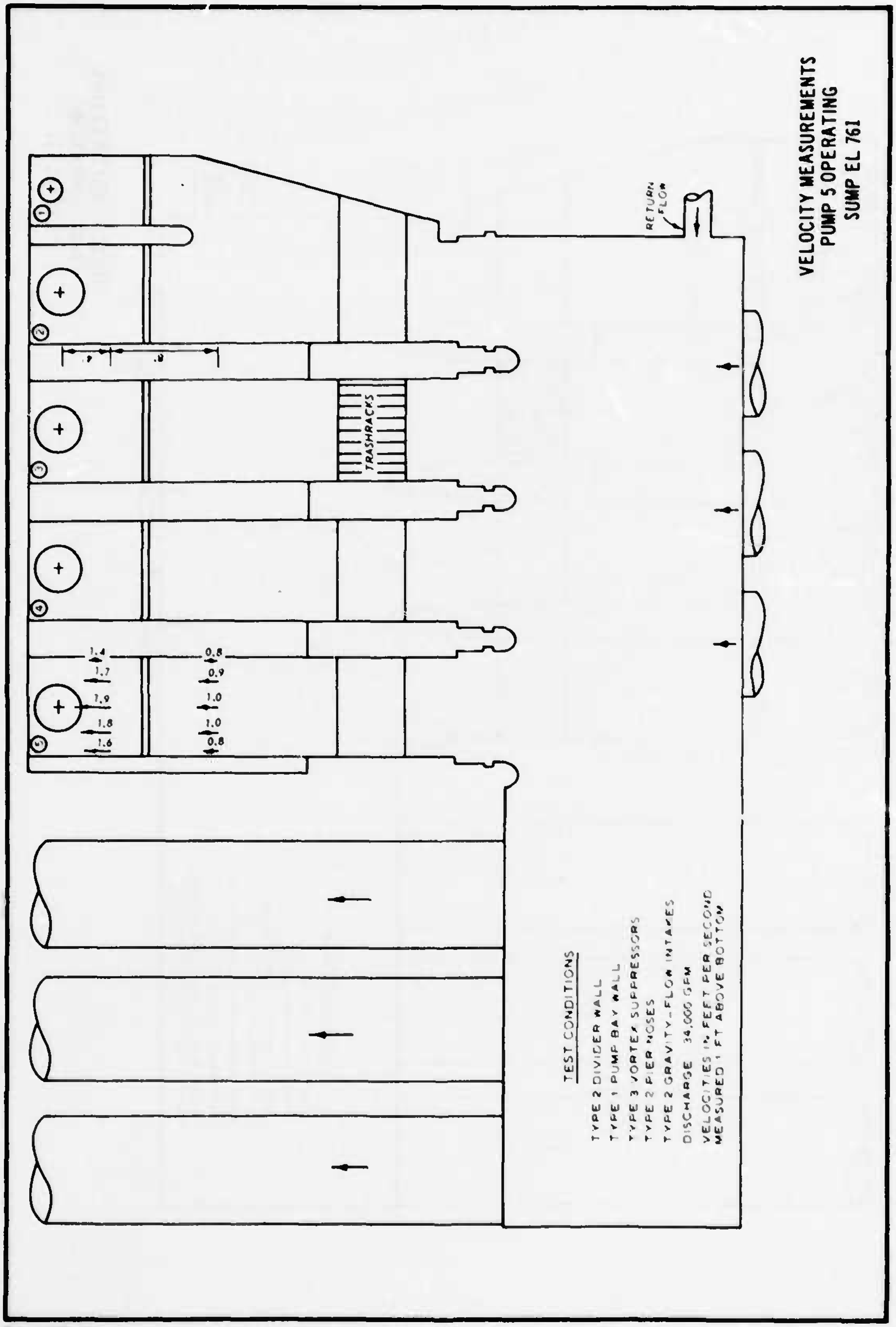
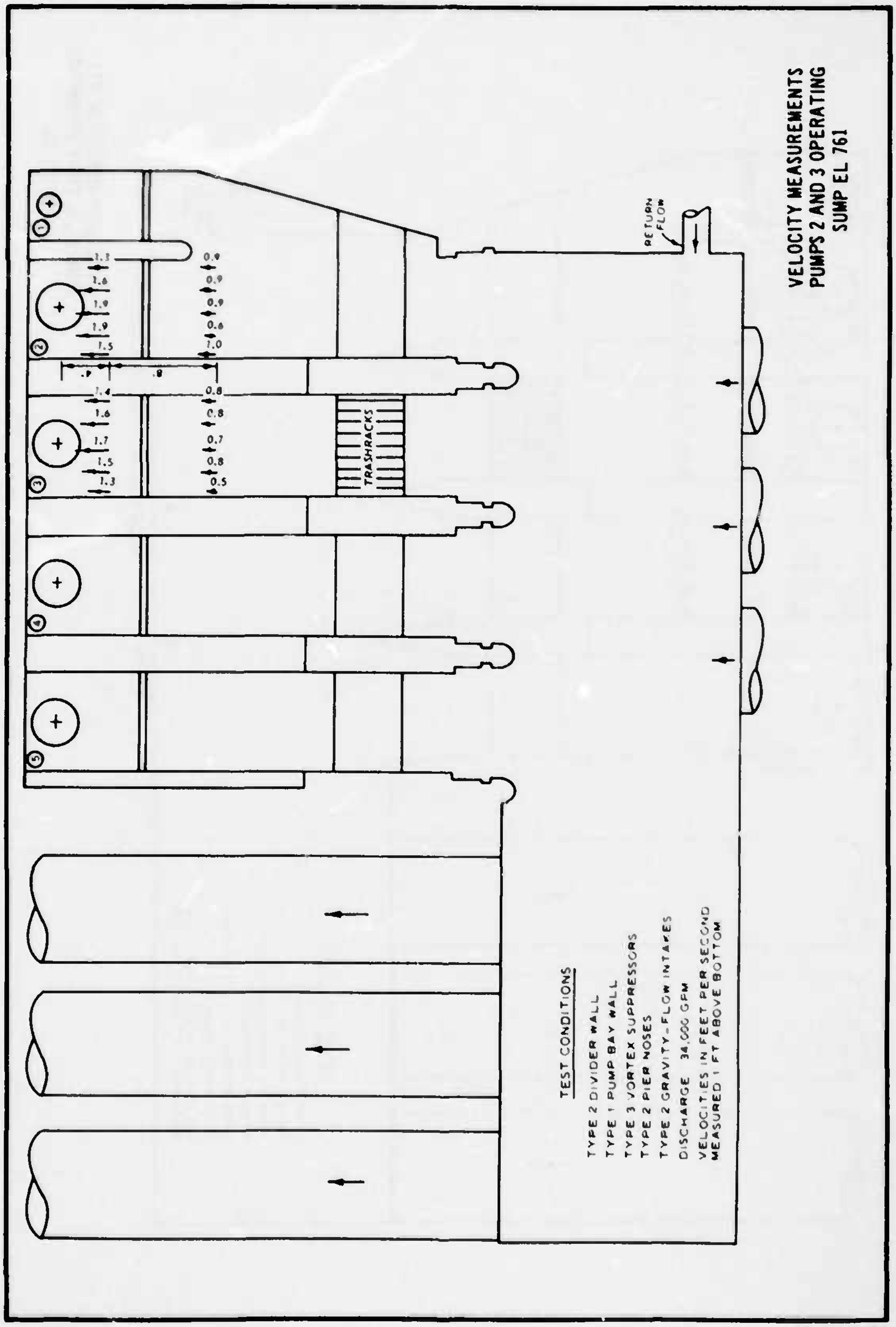

VELOCITY MEASUREMENTS
PUMP 5 OPERATING
SUMP EL 761
RETURN FLOW
TRASHRACKS
TEST CONDITIONS
TYPE 2 DIVIDER WALL
TYPE 1 PUMP BAY WALL
TYPE 3 VORTEX SUPPRESSORS
TYPE 2 PIER NOSES
TYPE 2 GRAVITY-FLOW INTAKES
DISCHARGE 34,000 GPM
VELOCITIES IN FEET PER SECOND
MEASURED 1 FT ABOVE BOTTOM
1.4
1.7
1.9
1.8
1.6
0.8
0.9
1.0
1.0
0.8

PLATE 20



VELOCITY MEASUREMENTS
PUMPS 2 AND 3 OPERATING
SUMP EL 761
RETURN FLOW
TRASHRACKS
TEST CONDITIONS
TYPE 2 DIVIDER WALL
TYPE 1 PUMP BAY WALL
TYPE 3 VORTEX SUPPRESSORS
TYPE 2 PIER NOSES
TYPE 2 GRAVITY-FLOW INTAKES
DISCHARGE 34,000 GPM
VELOCITIES IN FEET PER SECOND
MEASURED 1 FT ABOVE BOTTOM

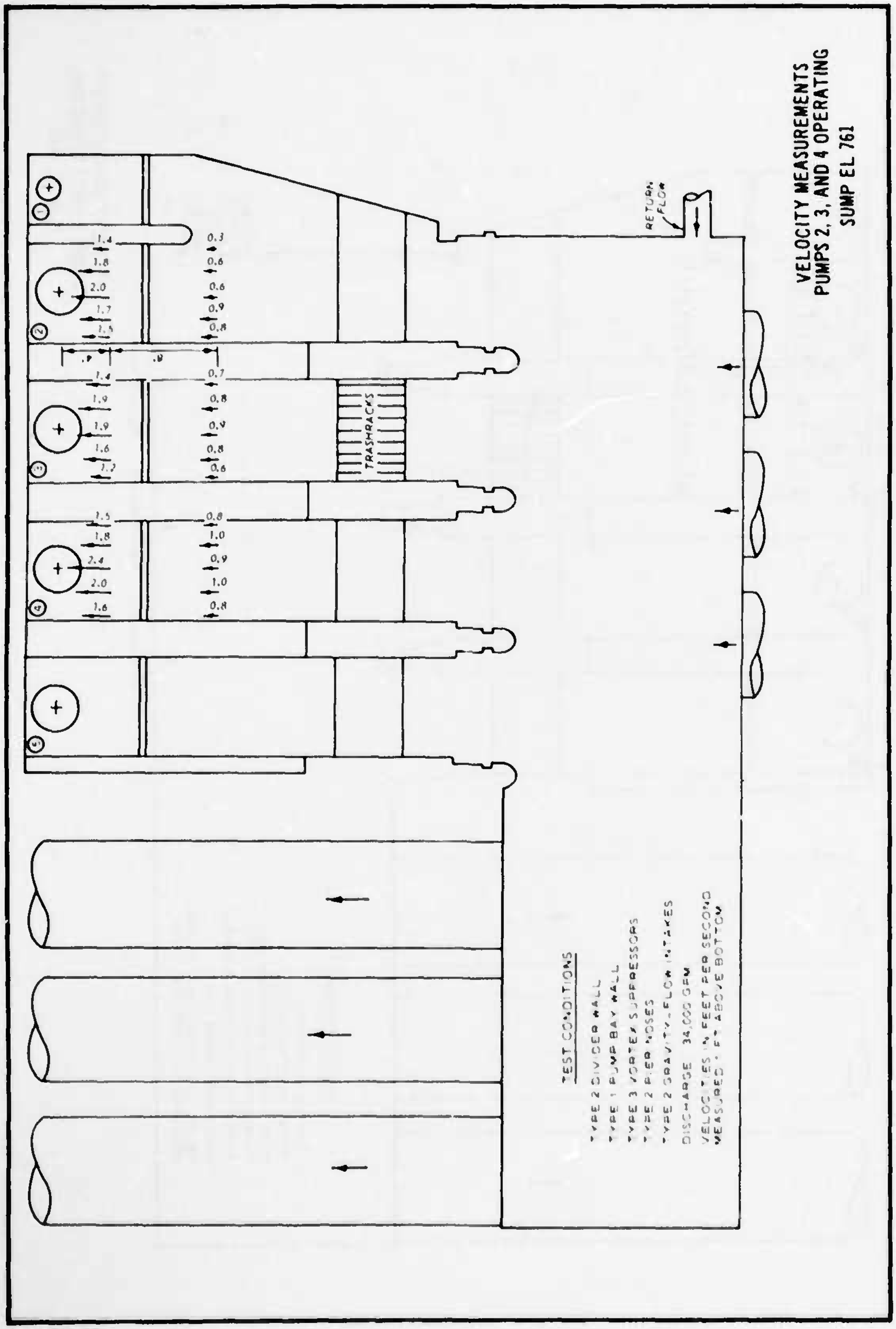
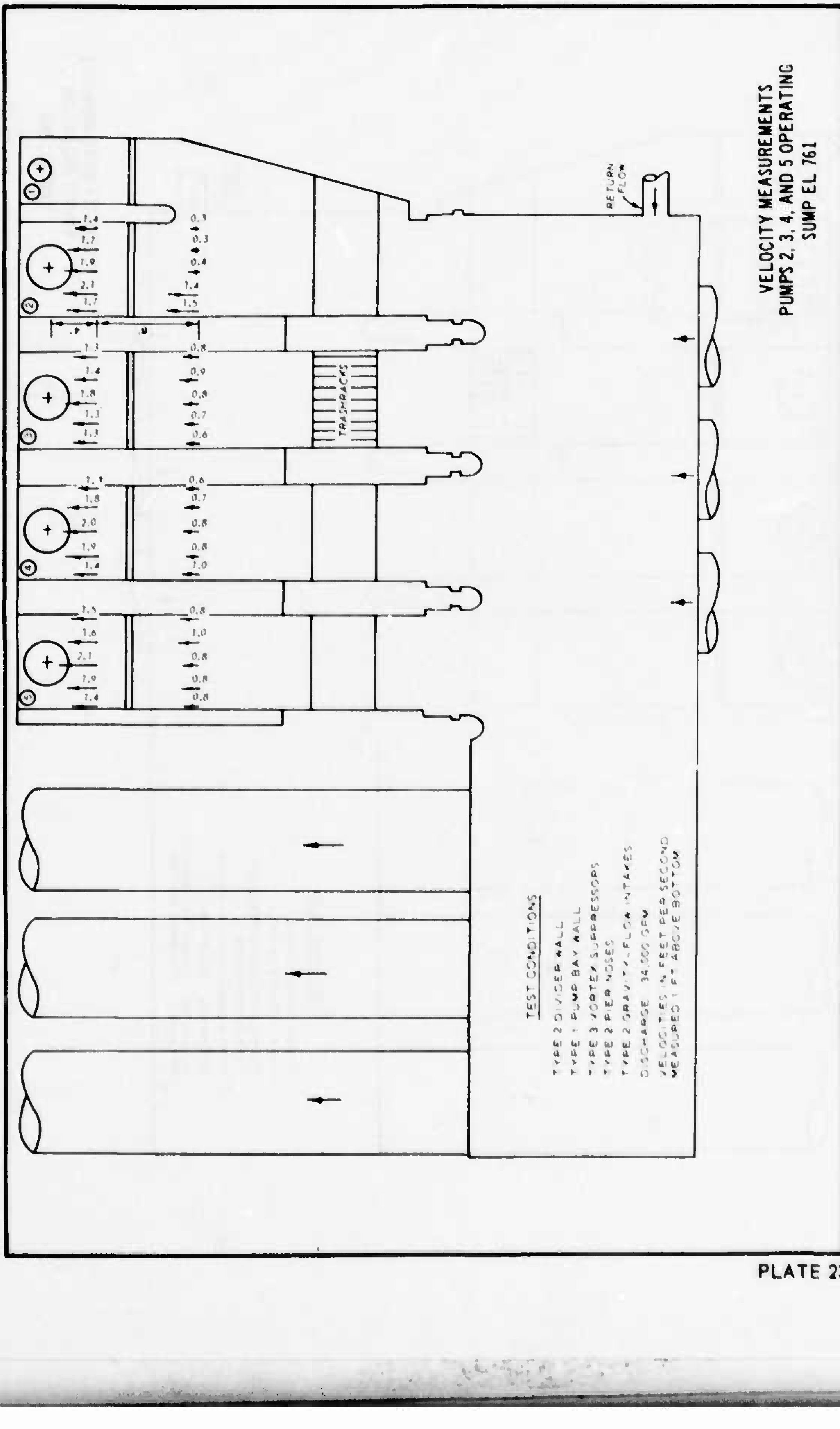
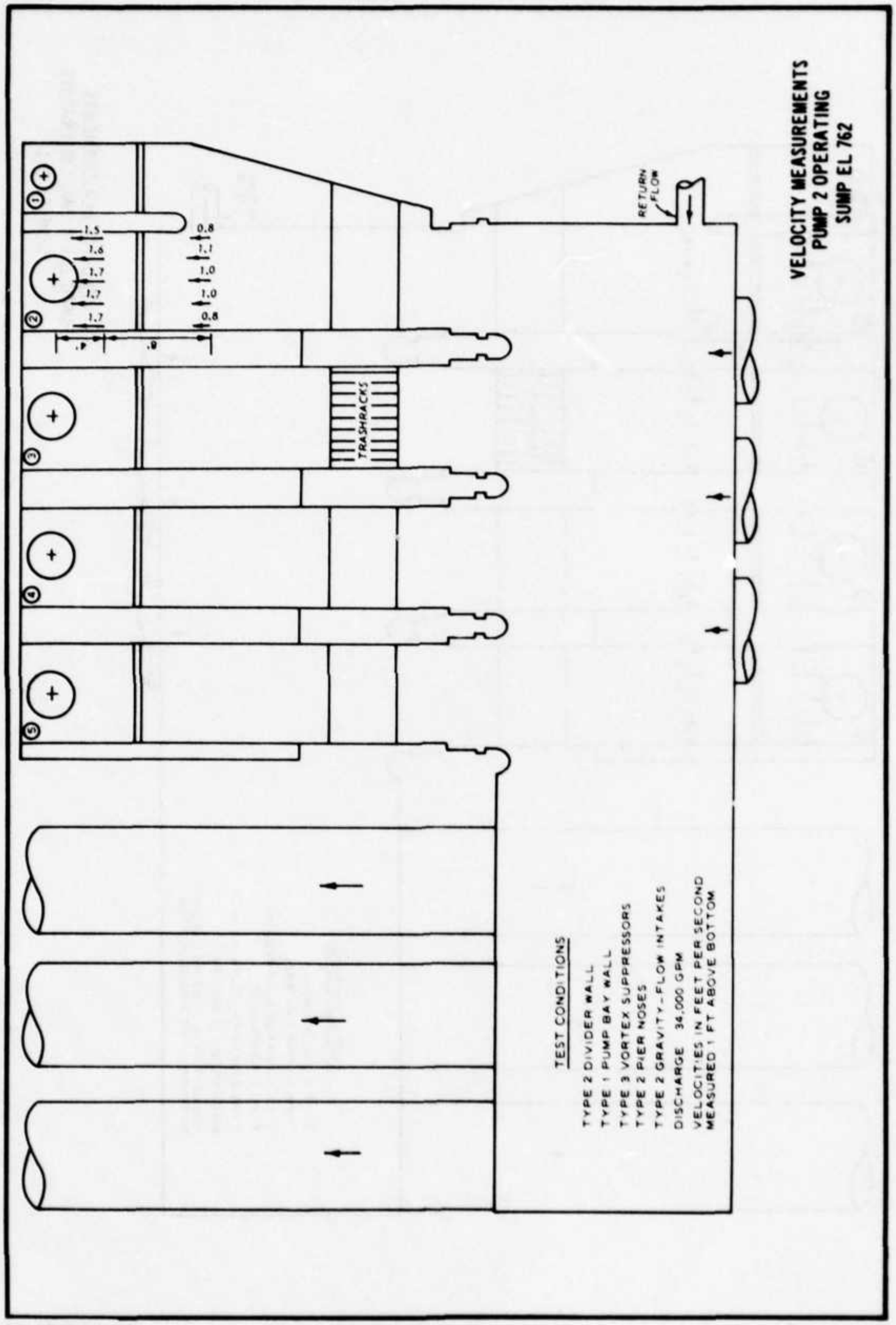
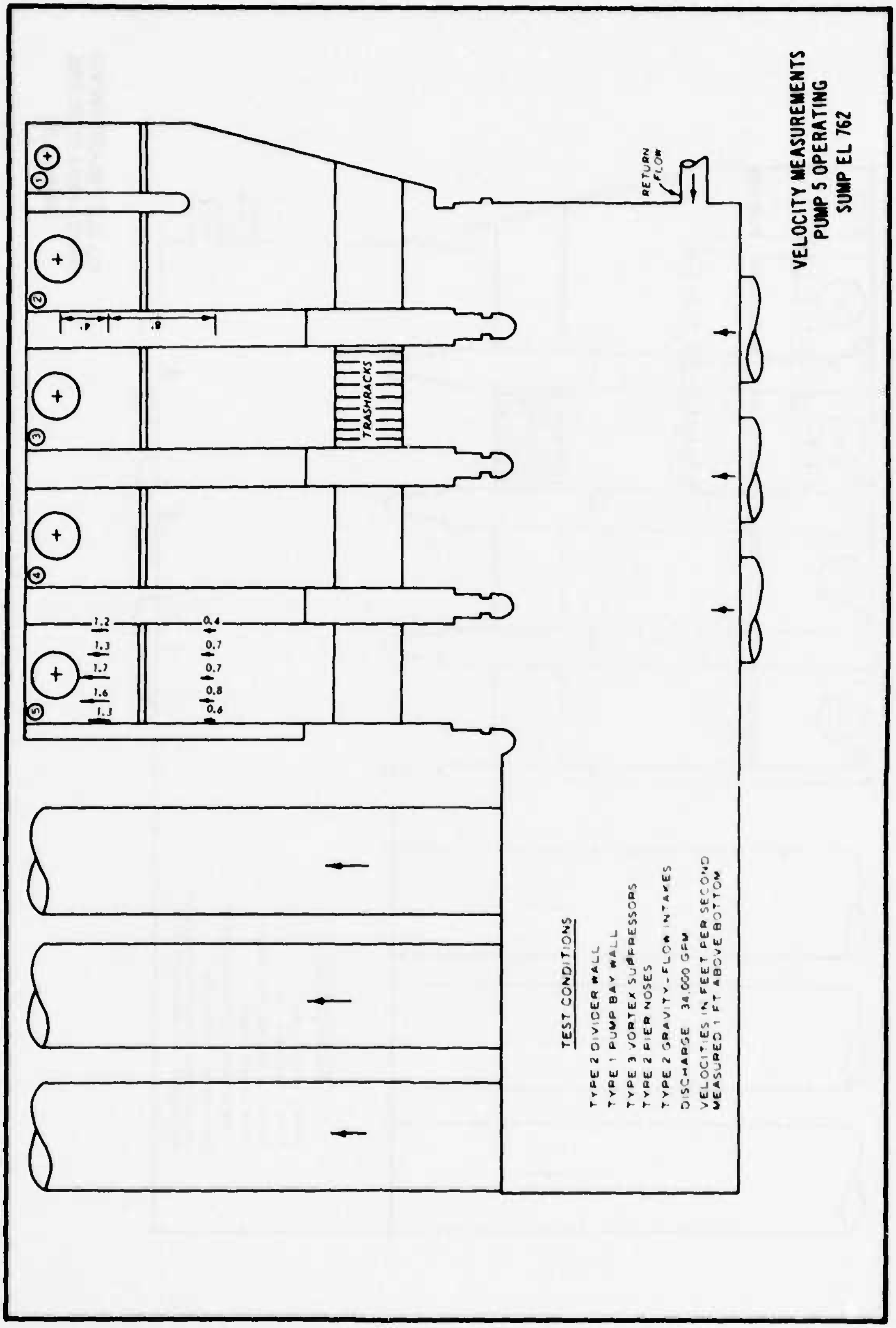

VELOCITY MEASUREMENTS
PUMPS 2, 3, AND 4 OPERATING
SUMP EL 761
RETURN FLOW
TRASHRACKS
TEST CONDITIONS
TYPE 2 DIVIDER WALL
TYPE 1 PUMP BAY WALL
TYPE 3 VORTEX SUPPRESSORS
TYPE 2 PIER NOSES
TYPE 2 GRAVITY-FLOW INTAKES
DISCHARGE 34,000 GPM
VELOCITIES IN FEET PER SECOND

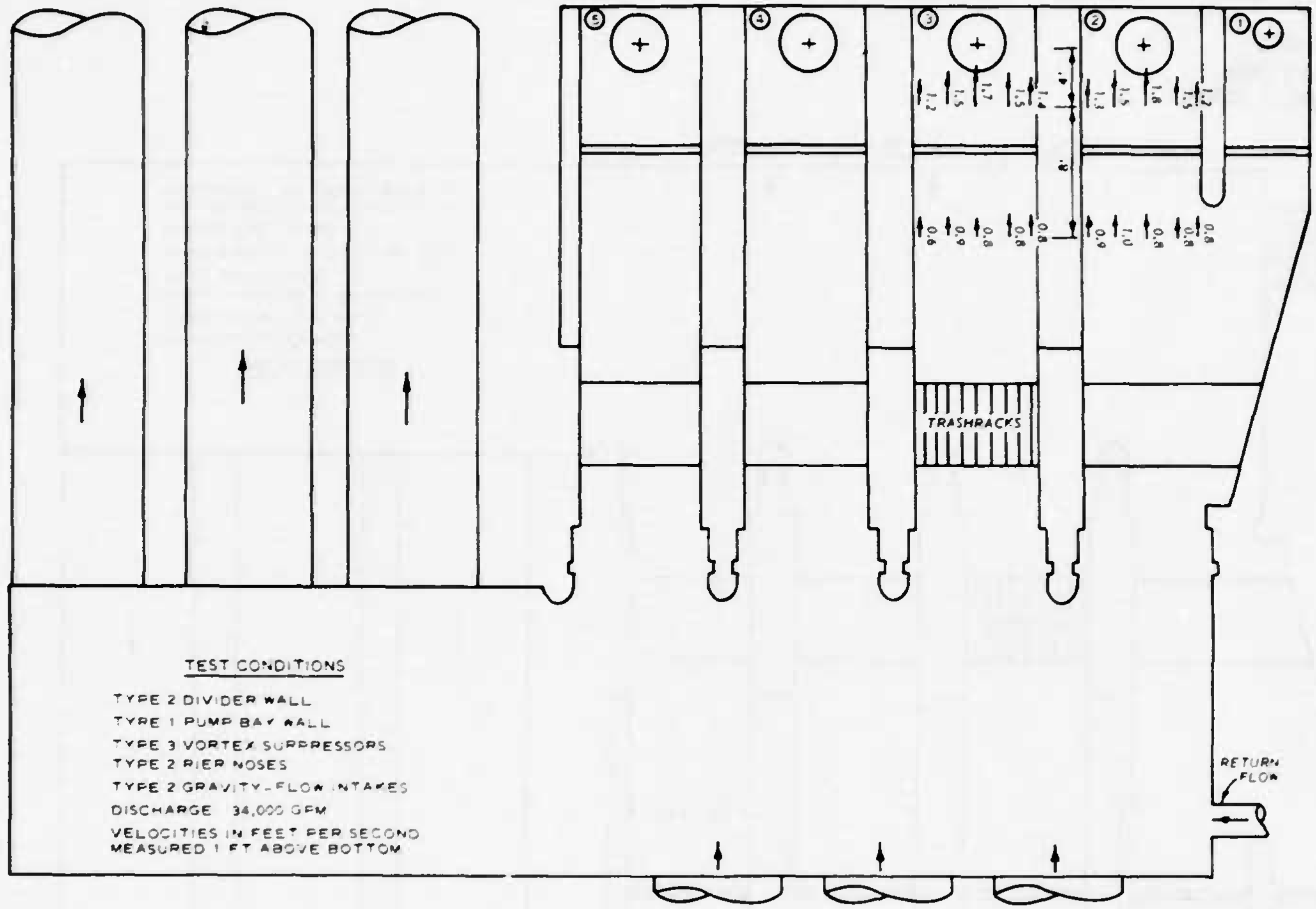
PLATE 22


VELOCITY MEASUREMENTS
PUMPS 2, 3, 4, AND 5 OPERATING
SUMP EL 761
RETURN FLOW
TRASHRACKS
TEST CONDITIONS
TYPE 2 DIVIDER WALL
TYPE 1 PUMP BAY WALL
TYPE 3 VORTEX SUPPRESSORS
TYPE 2 PIER NOSES
TYPE 2 GRAVITY-FLOW INTAKES
DISCHARGE 34,500 GPM
VELOCITIES IN FEET PER SECOND
MEASURED 1 FT ABOVE BOTTOM

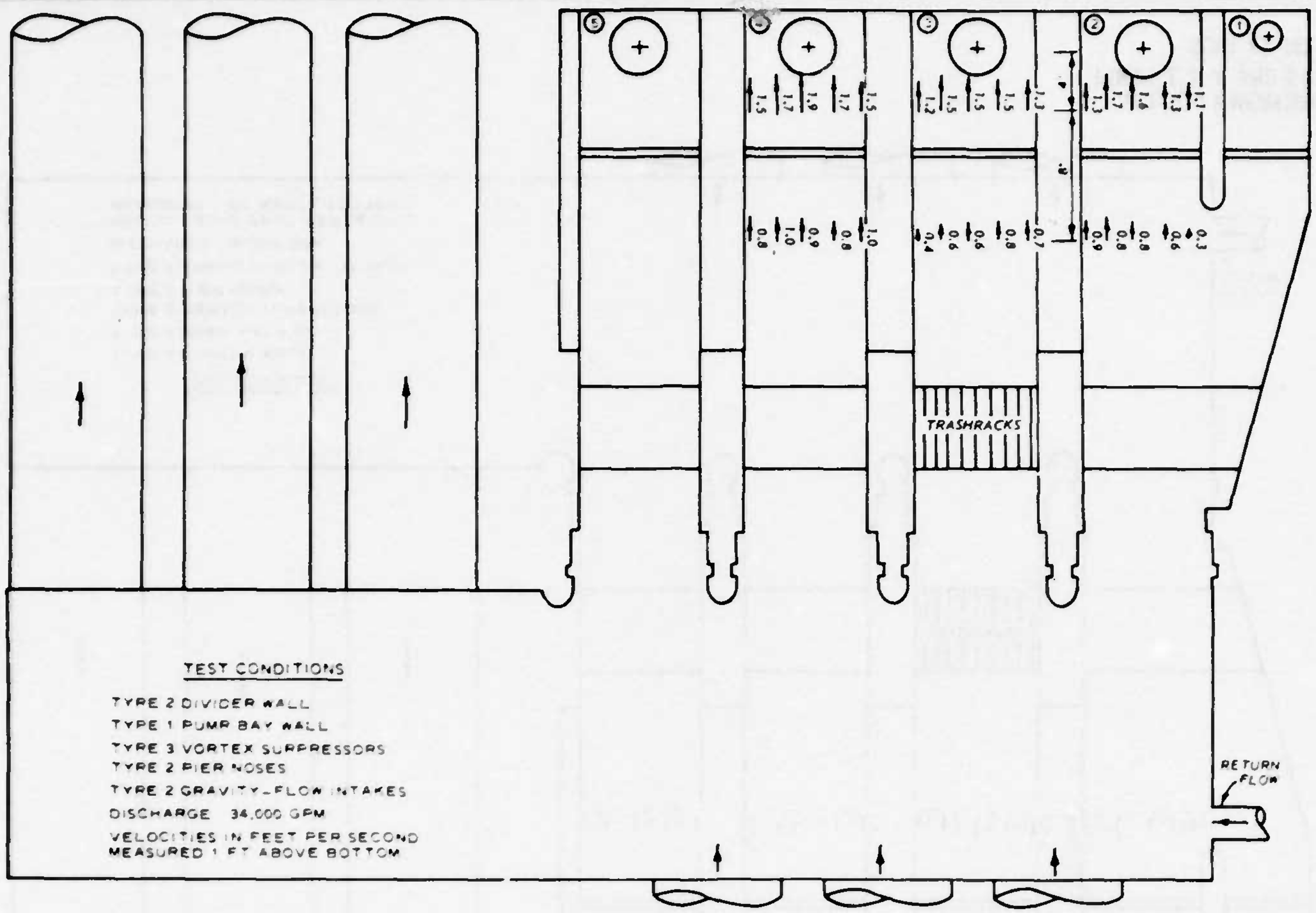


VELOCITY MEASUREMENTS
PUMP 2 OPERATING
SUMP EL 762


TEST CONDITIONS
TYPE 2 DIVIDER WALL
TYPE 1 PUMP BAY WALL
TYPE 3 VORTEX SUPPRESSORS
TYPE 2 PIER NOSES
TYPE 2 GRAVITY-FLOW INTAKES
DISCHARGE 34,000 GPM
VELOCITIES IN FEET PER SECOND
MEASURED 1 FT ABOVE BOTTOM
TRASHRACKS
RETURN FLOW
1
2
3
4
5
4'
8'
1.2
1.3
1.7
1.6
1.3
0.4
0.7
0.7
0.8
0.6
VELOCITY MEASUREMENTS
PUMP 5 OPERATING
SUMP EL 762



VELOCITY MEASUREMENTS
PUMPS 2 AND 3 OPERATING
SUMP EL 762



VELOCITY MEASUREMENTS
PUMPS 2, 3, AND 4 OPERATING
SUMP EL 762

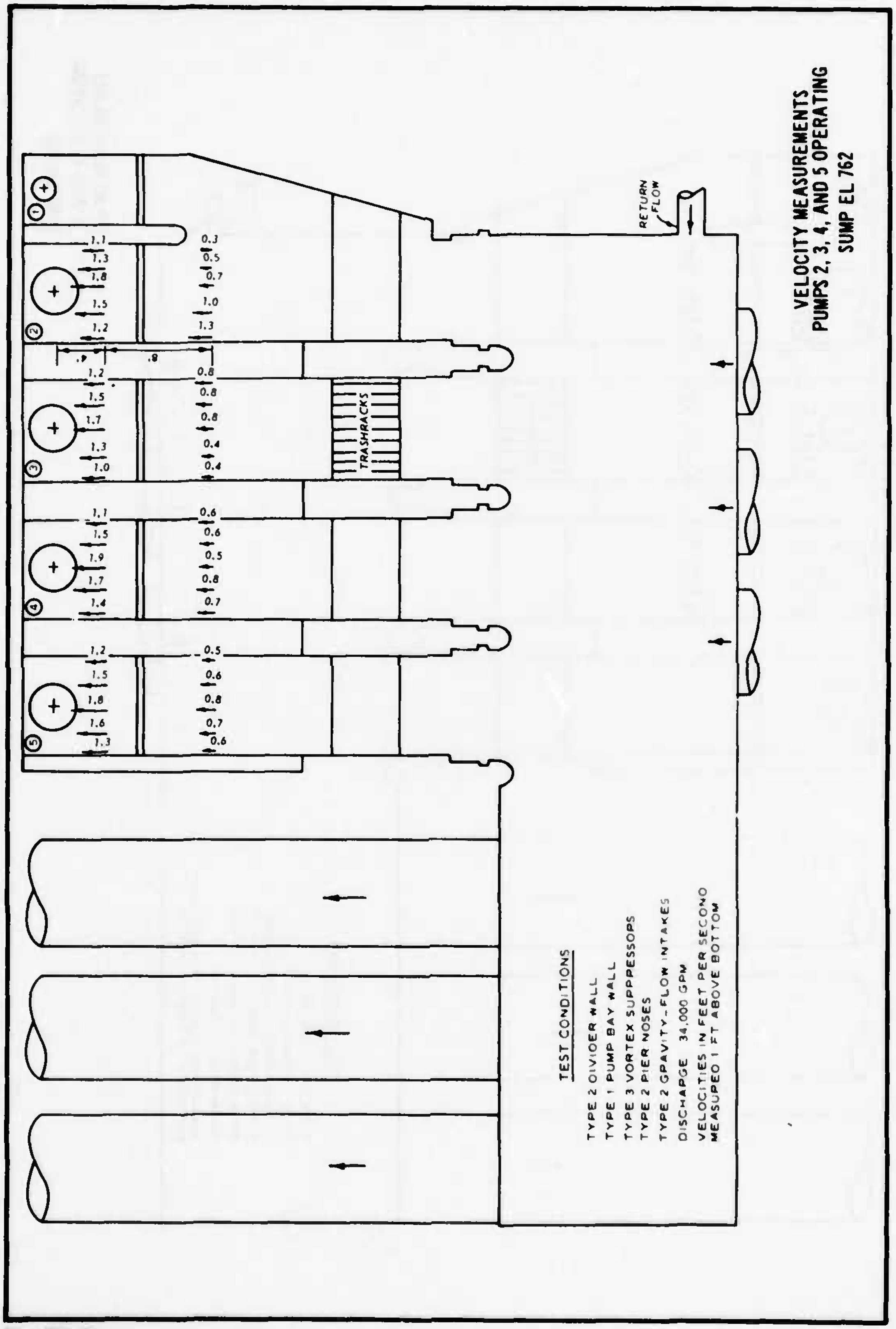
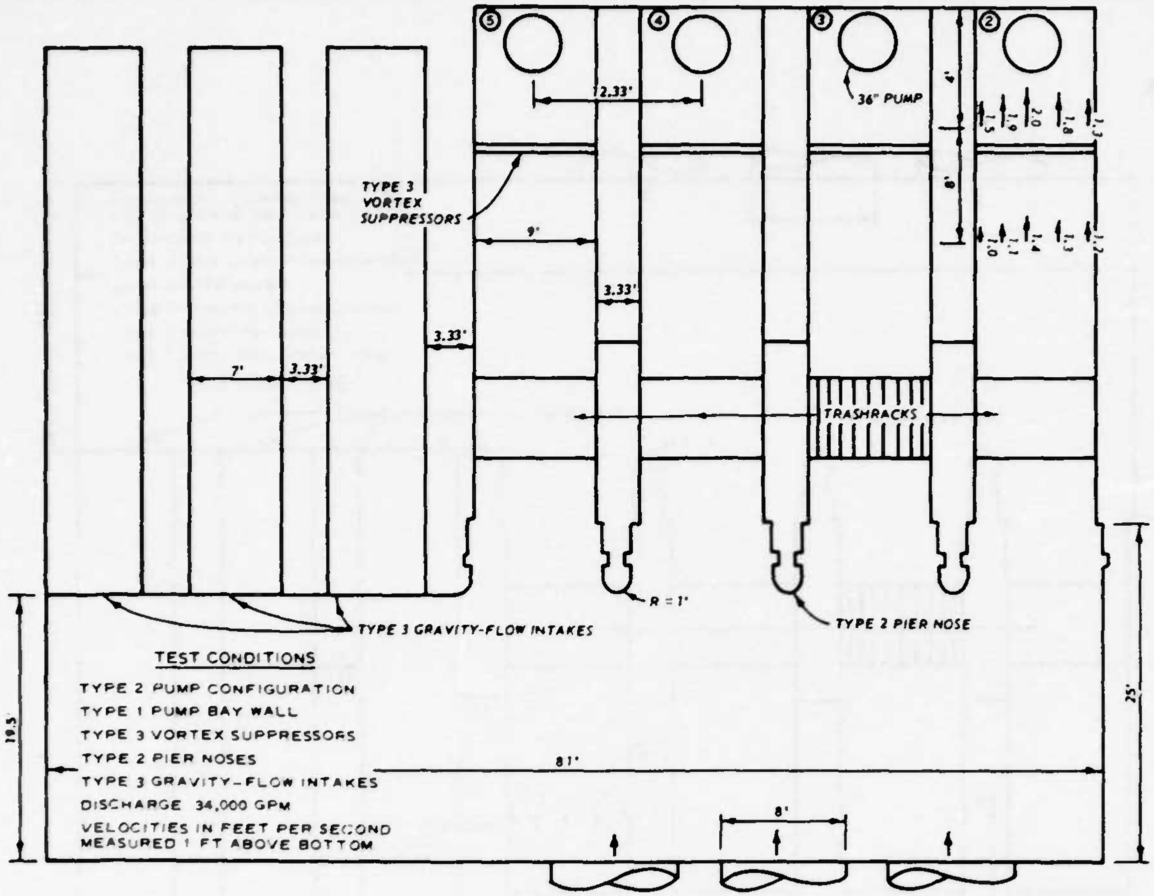
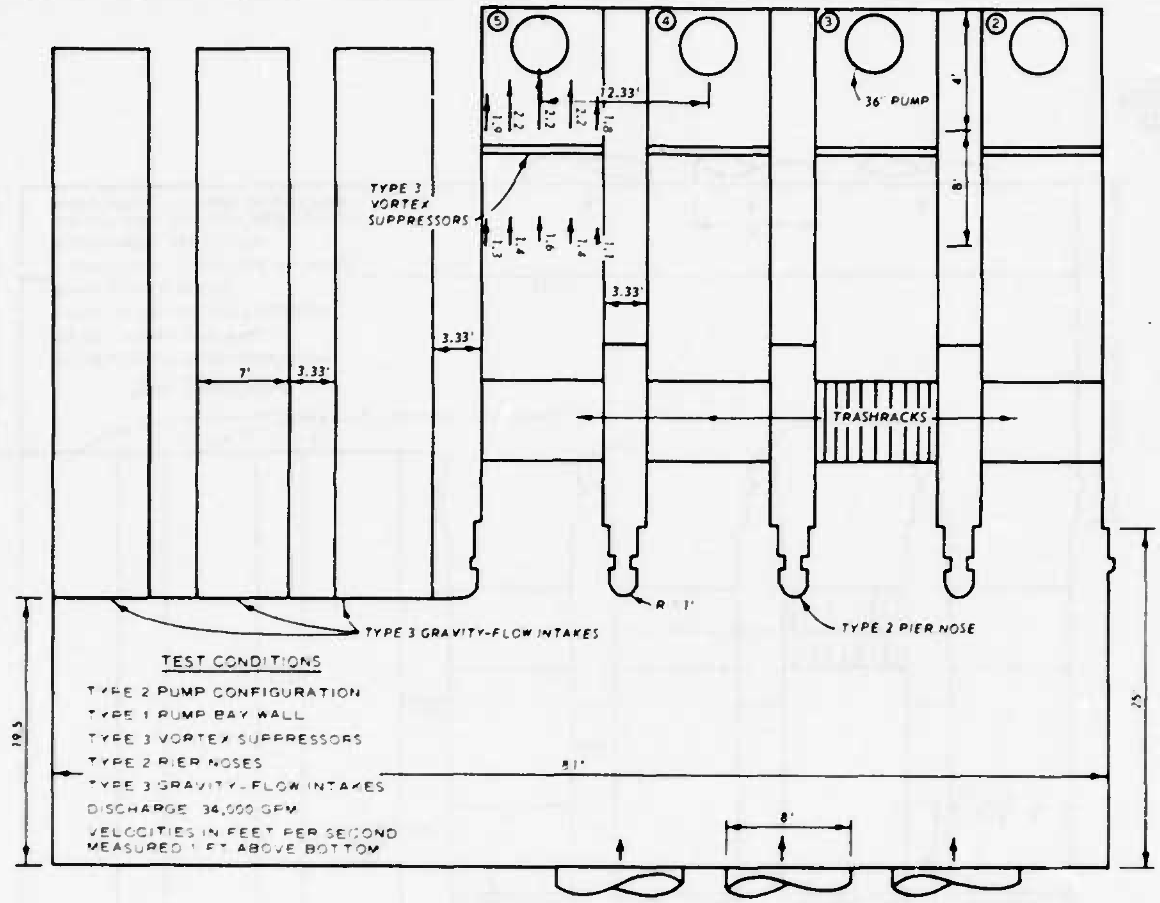

VELOCITY MEASUREMENTS
PUMPS 2, 3, 4, AND 5 OPERATING
SUMP EL 762
RETURN FLOW
TRASHRACKS
TEST CONDITIONS
TYPE 2 DIVIDER WALL
TYPE 1 PUMP BAY WALL
TYPE 3 VORTEX SUPPRESSORS
TYPE 2 PIER NOSES
TYPE 2 GRAVITY-FLOW INTAKES
DISCHARGE 34,000 GPM
VELOCITIES IN FEET PER SECOND
MEASURED 1 FT ABOVE BOTTOM

PLATE 28



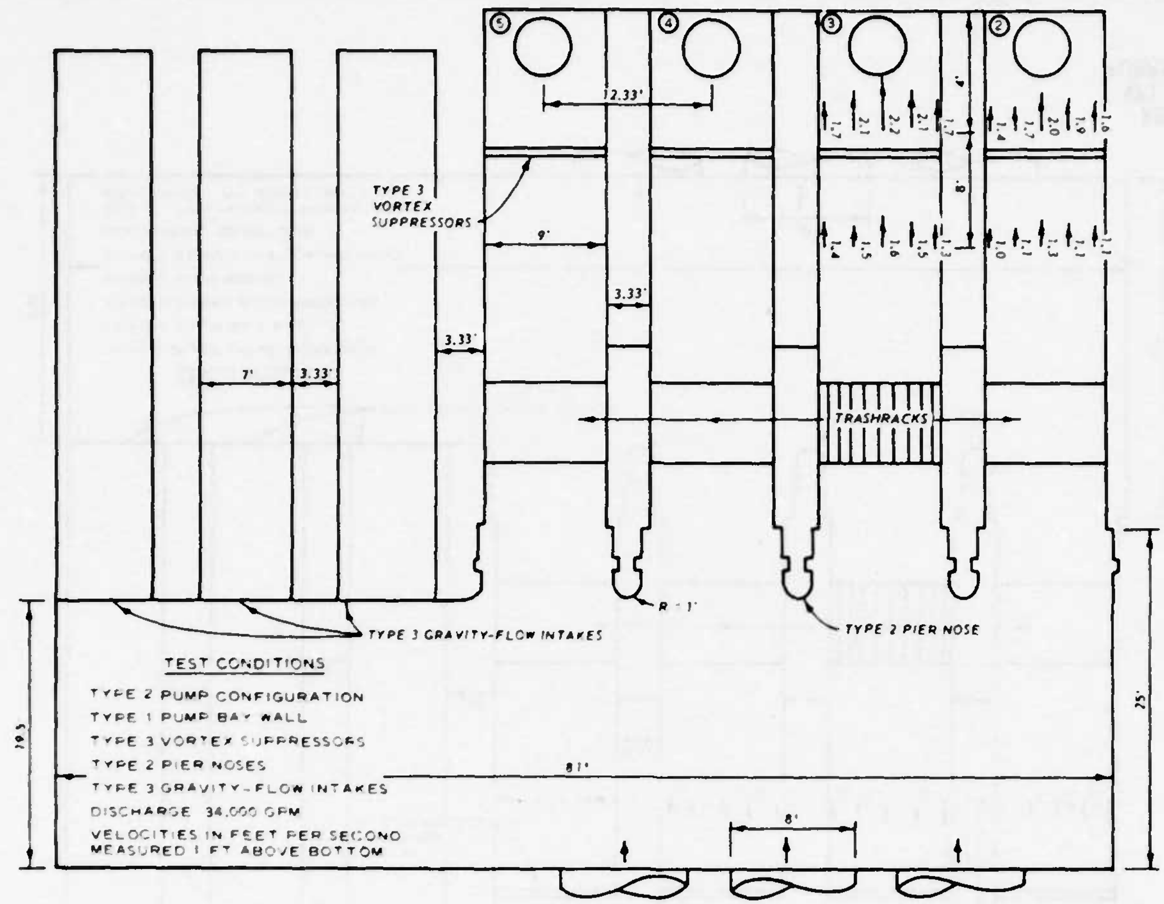
RECOMMENDED DESIGN
VELOCITY MEASUREMENTS
PUMP 2 OPERATING
SUMP EL 757

PLATE 29

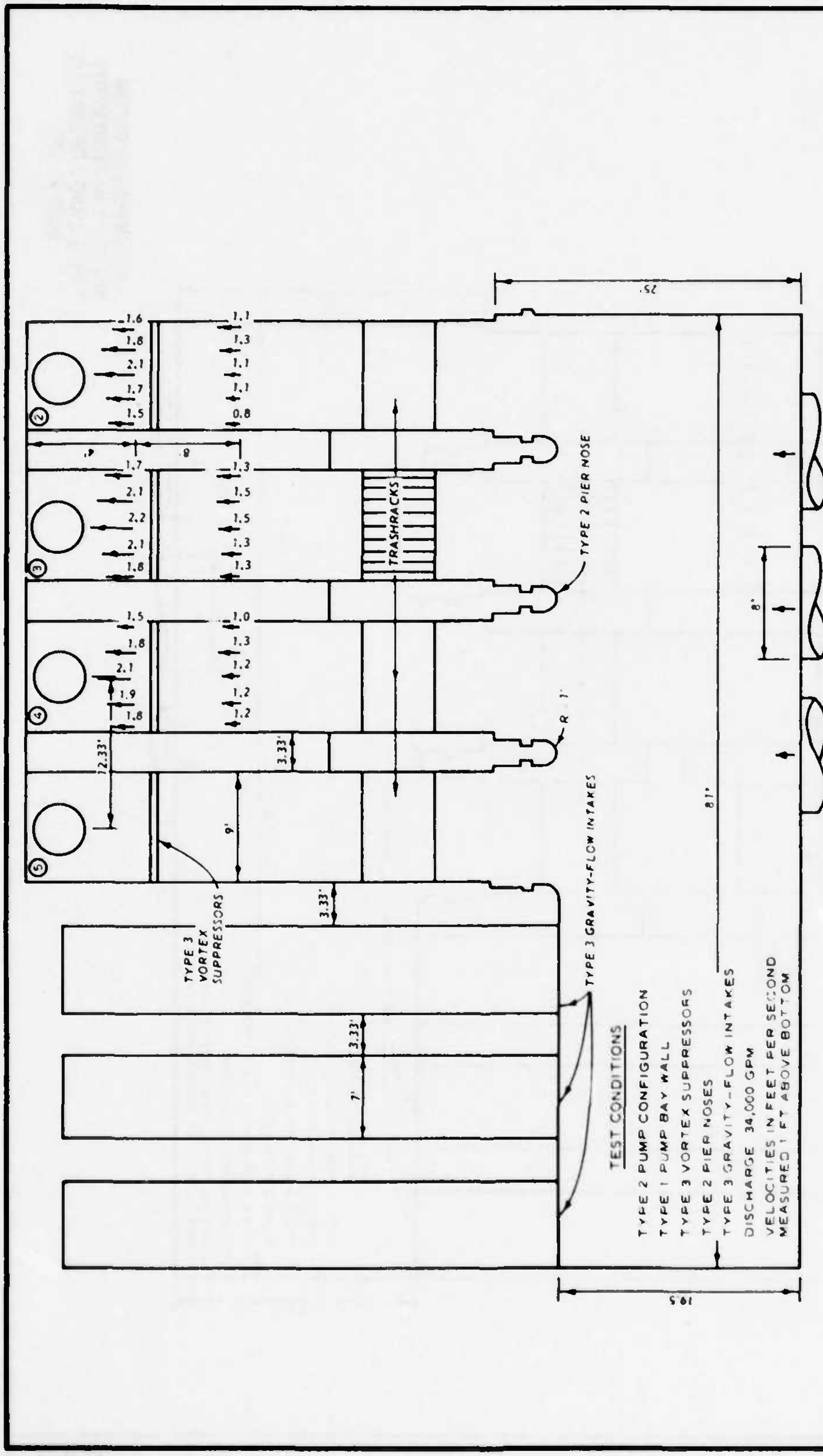


RECOMMENDED DESIGN
VELOCITY MEASUREMENTS
PUMP 5 OPERATING
SUMP EL 757

PLATE 30

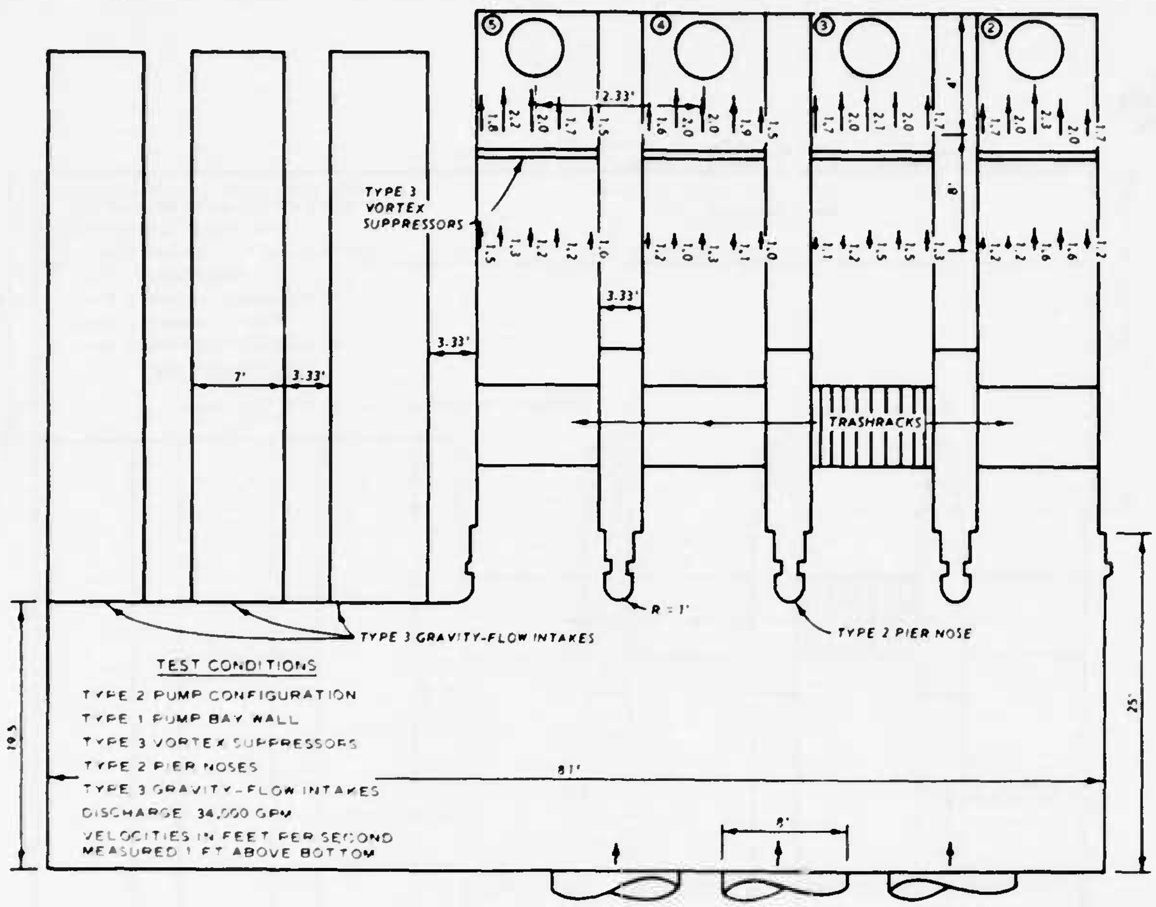


RECOMMENDED DESIGN
VELOCITY MEASUREMENTS
PUMPS 2 AND 3 OPERATING
SUMP EL 757



RECOMMENDED DESIGN
VELOCITY MEASUREMENTS
PUMPS 2, 3, AND 4 OPERATING
SUMP EL 757

PLATE 32



RECOMMENDED DESIGN
VELOCITY MEASUREMENTS
PUMPS 2, 3, 4, AND 5 OPERATING
SUMP EL 757

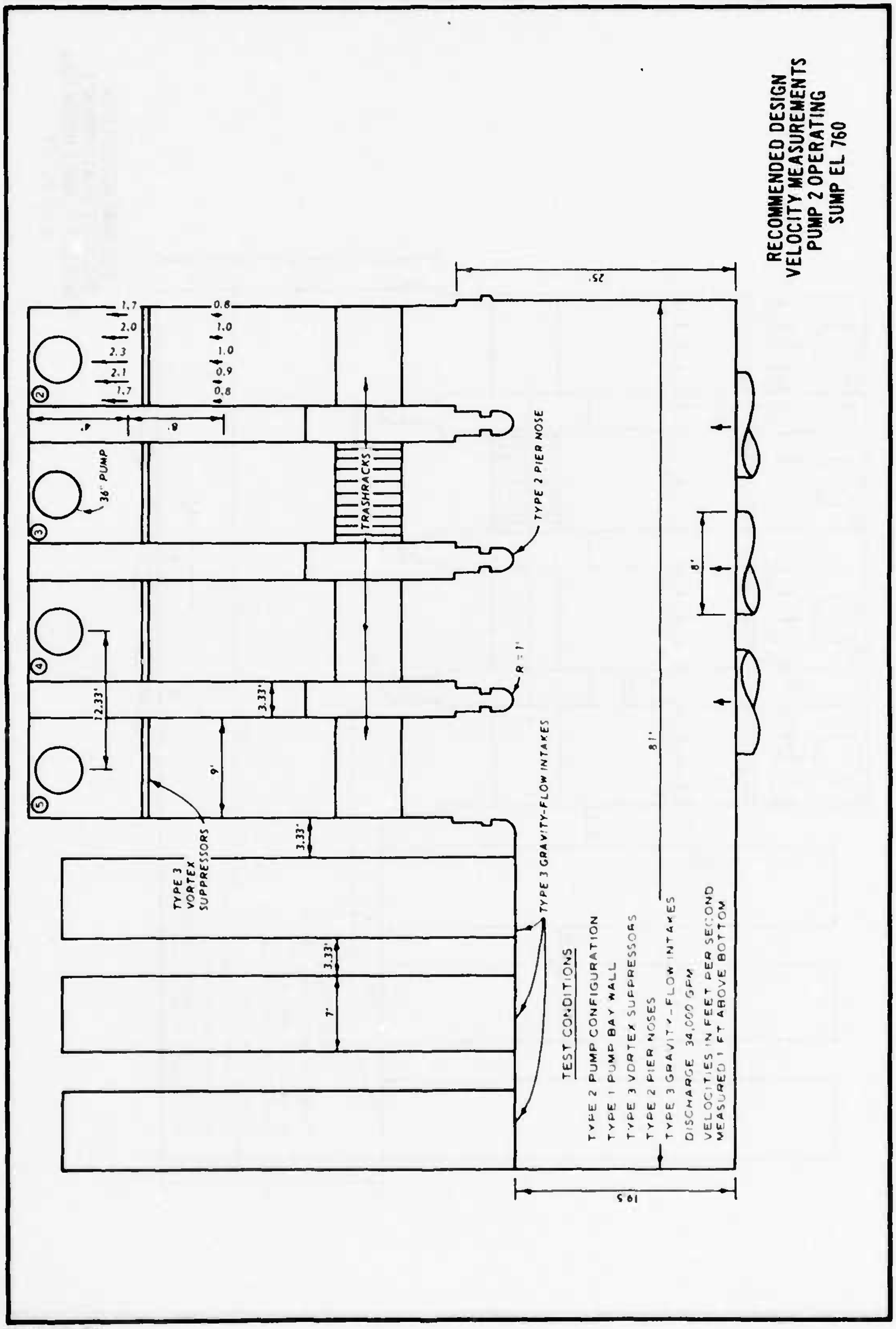
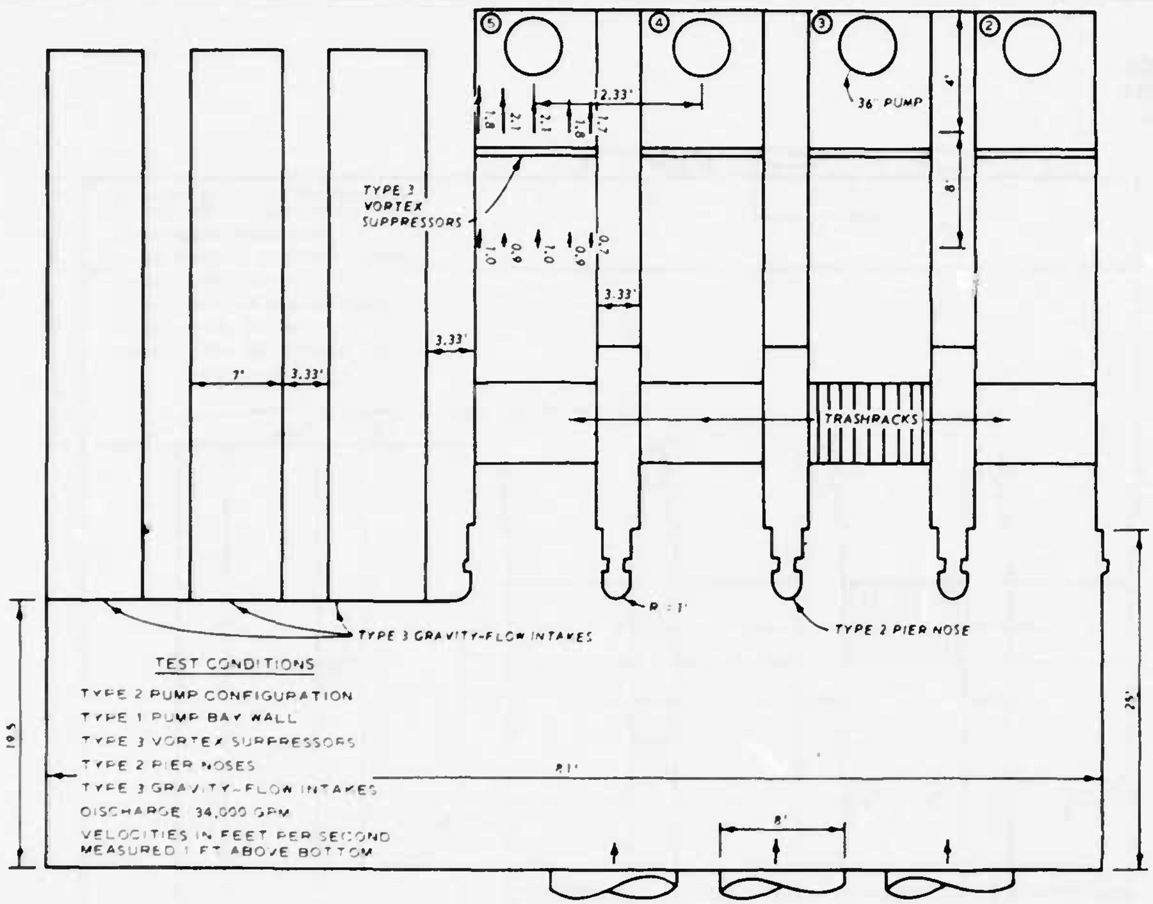
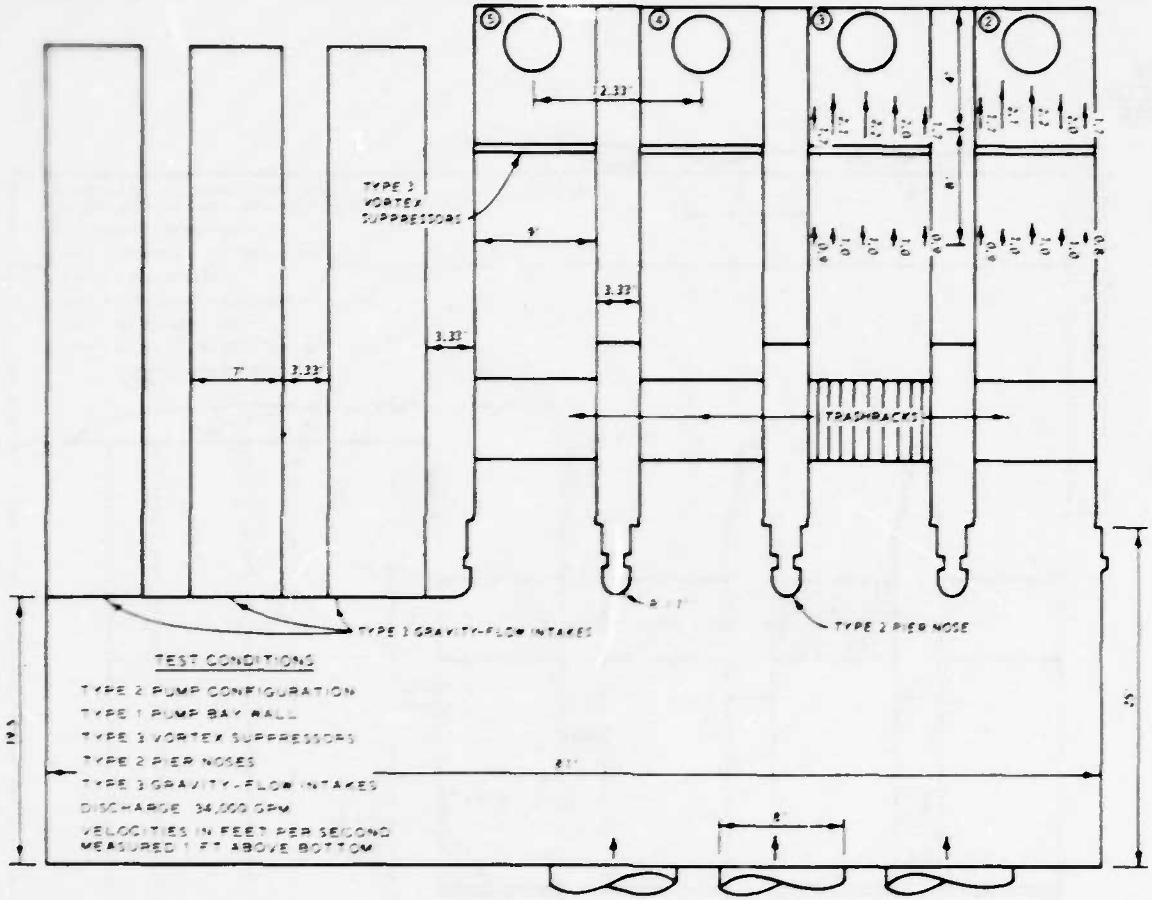

RECOMMENDED DESIGN
VELOCITY MEASUREMENTS
PUMP 2 OPERATING
SUMP EL 760
TEST CONDITIONS
TYPE 2 PUMP CONFIGURATION
TYPE 1 PUMP BAY WALL
TYPE 3 VORTEX SUPPRESSORS
TYPE 2 PIER NOSES
TYPE 3 GRAVITY-FLOW INTAKES
DISCHARGE 34,000 GPM
VELOCITIES IN FEET PER SECOND
MEASURED 1 FT ABOVE BOTTOM
TYPE 3 VORTEX SUPPRESSORS
TYPE 3 GRAVITY-FLOW INTAKES
TYPE 2 PIER NOSE
TRASHRACKS
36" PUMP
R = 1'
1.7
2.0
2.3
2.1
1.7
0.8
1.0
1.0
0.9
0.8
12.33'
3.33'
3.33'
3.33'
9'
7'
8'
81'
25'
19.5
2
3
4
5

PLATE 34

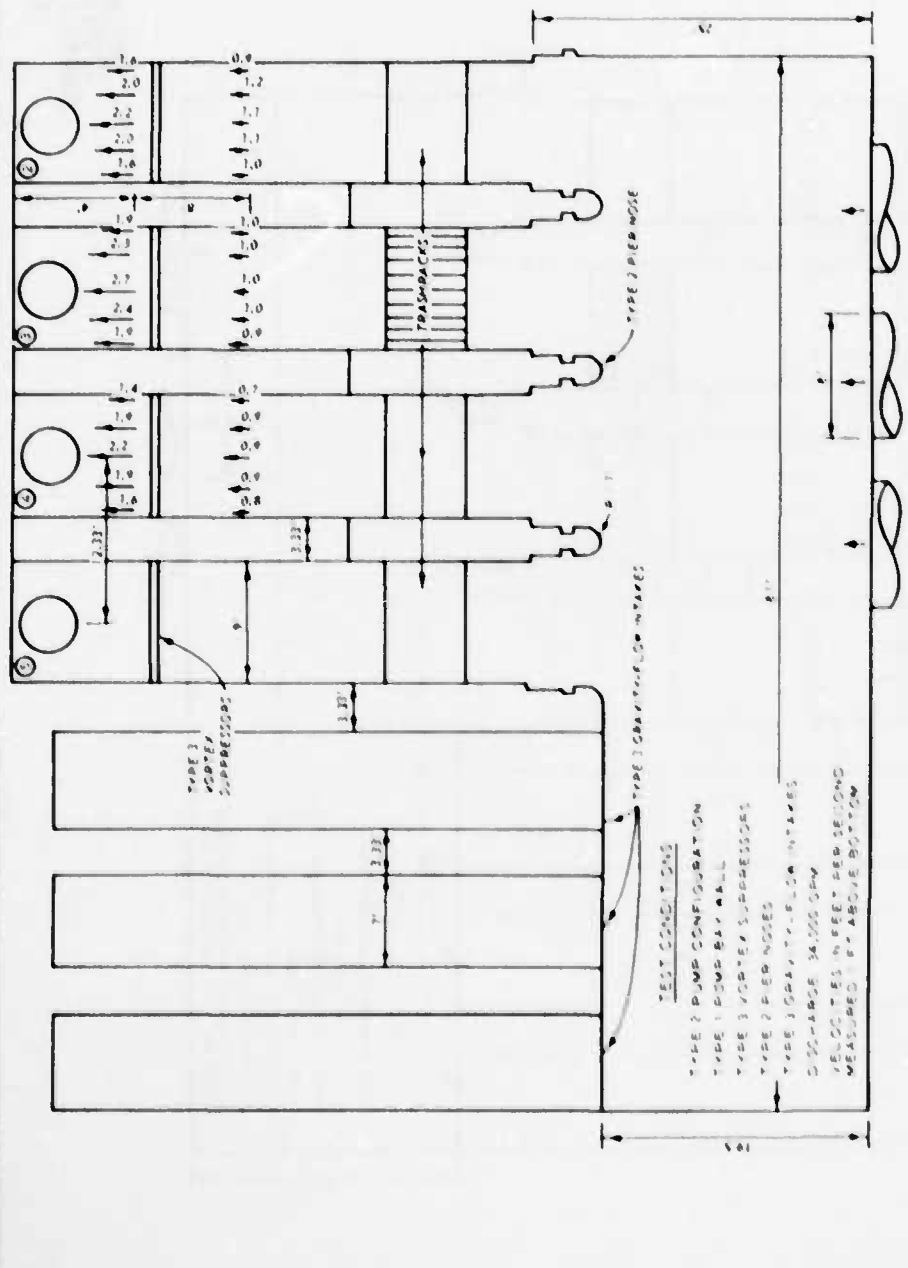


RECOMMENDED DESIGN
VELOCITY MEASUREMENTS
PUMP 5 OPERATING
SUMP EL 760

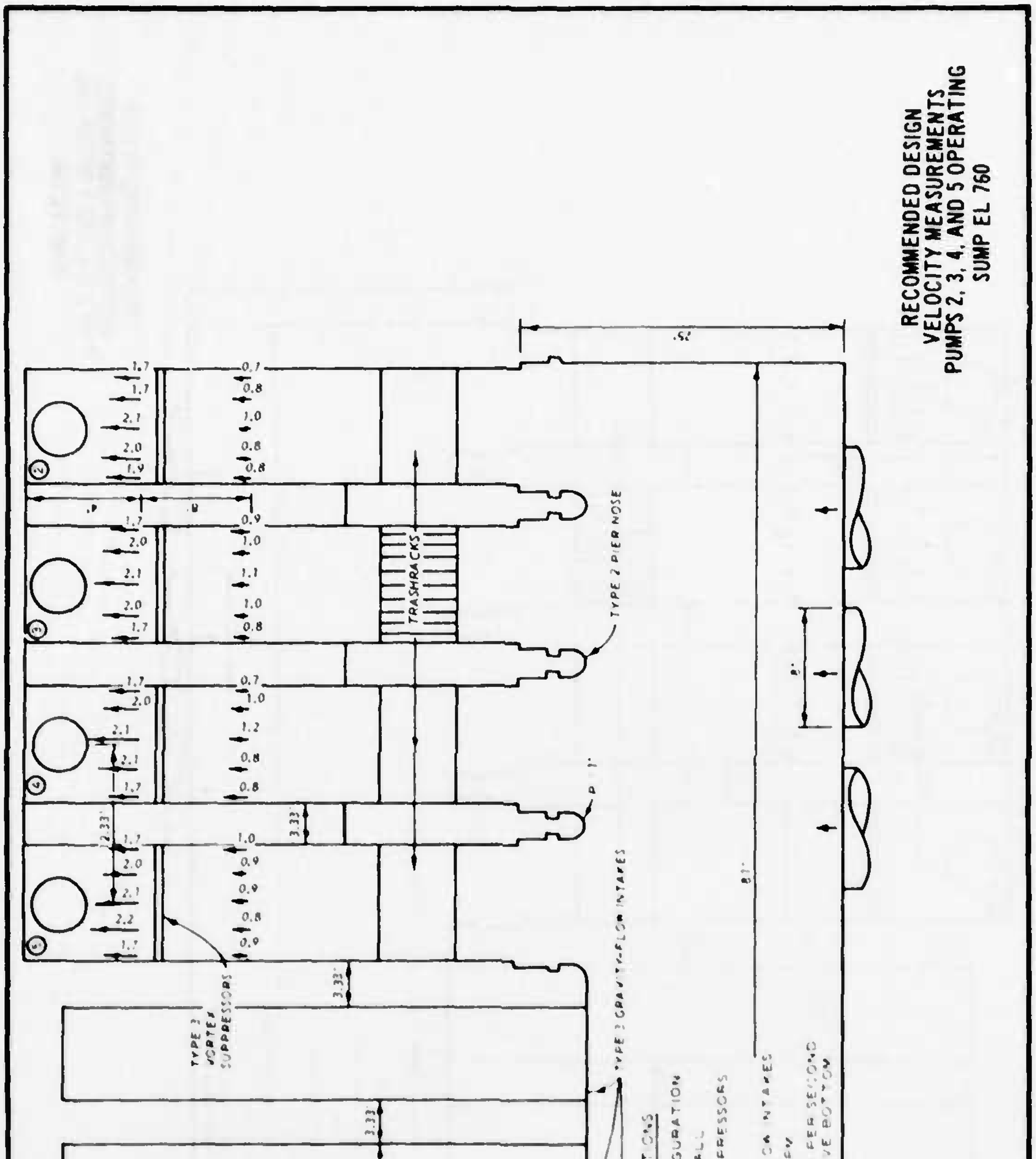
PLATE 35

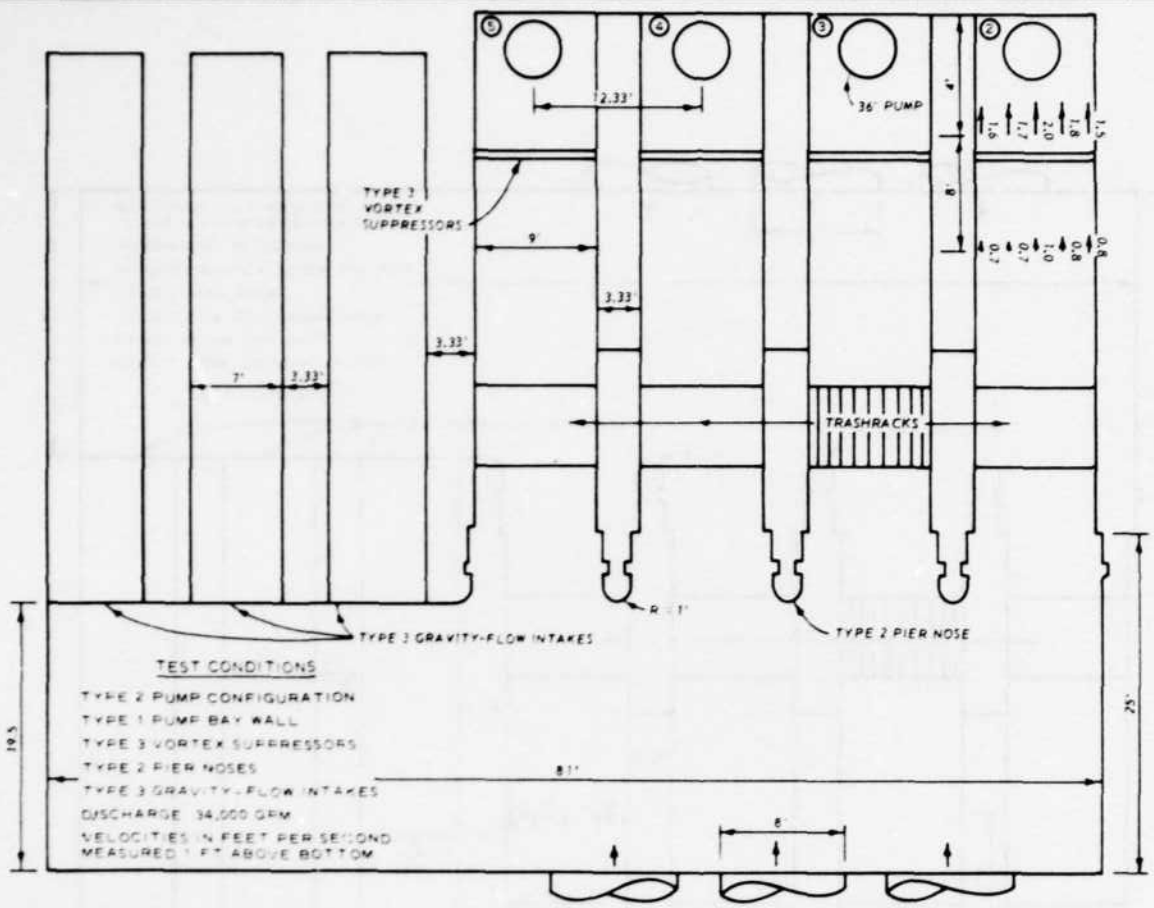


RECOMMENDED DESIGN
VELOCITY MEASUREMENTS
PUMPS 2 AND 3 OPERATING
SUMP EL 760



RECOMMENDED DESIGN
VELOCITY MEASUREMENTS
PUMPS 2, 3, AND 4 OPERATING
SUMP EL 760


RECOMMENDED DESIGN
VELOCITY MEASUREMENTS
PUMPS 2, 3, 4, AND 5 OPERATING
SUMP EL 760
TRASHRACKS
TYPE 2 PIER NOSE
TEST CONDITIONS
PUMP CONFIGURATION



RECOMMENDED DESIGN
VELOCITY MEASUREMENTS
PUMP 2 OPERATING
SUMP EL 761

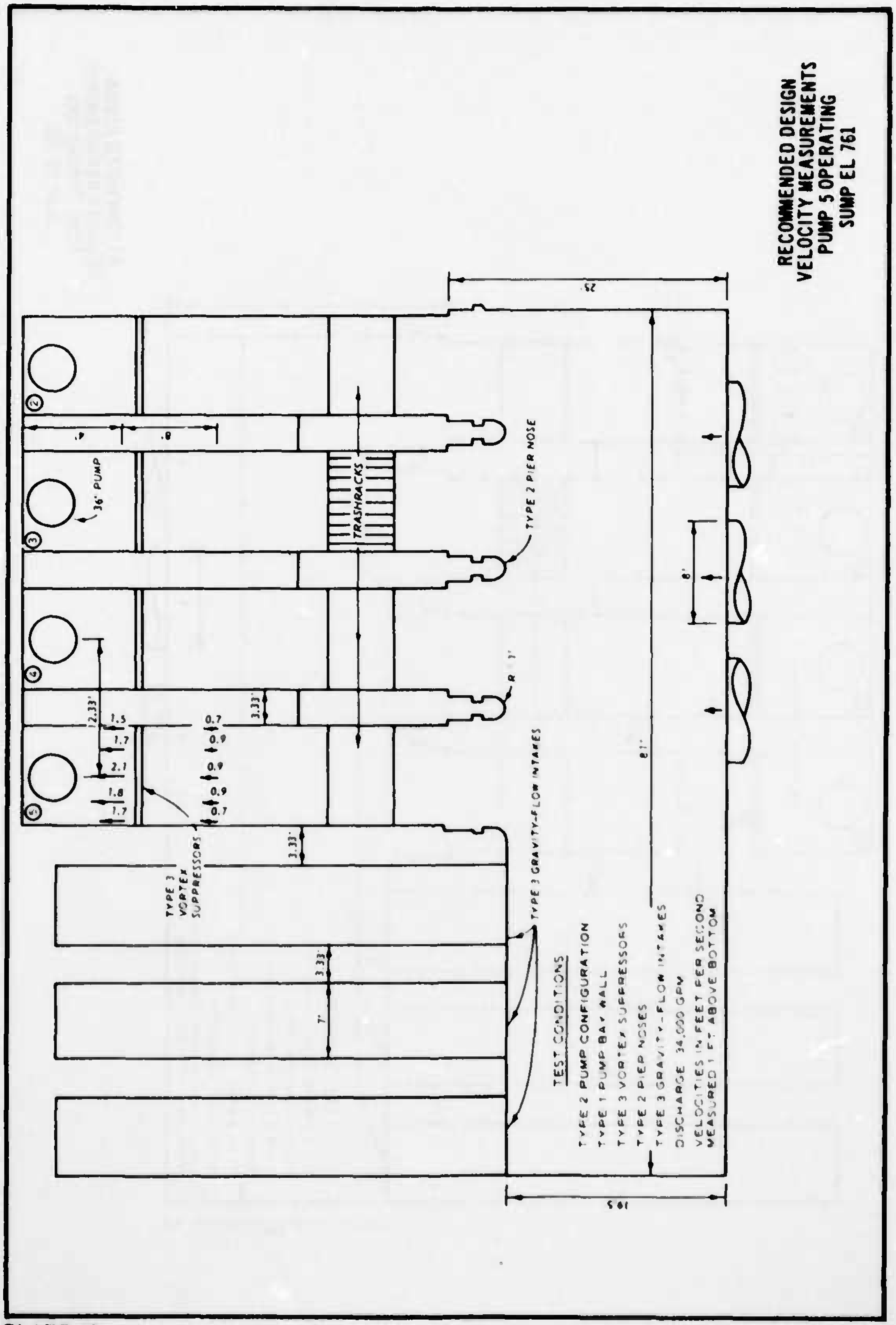
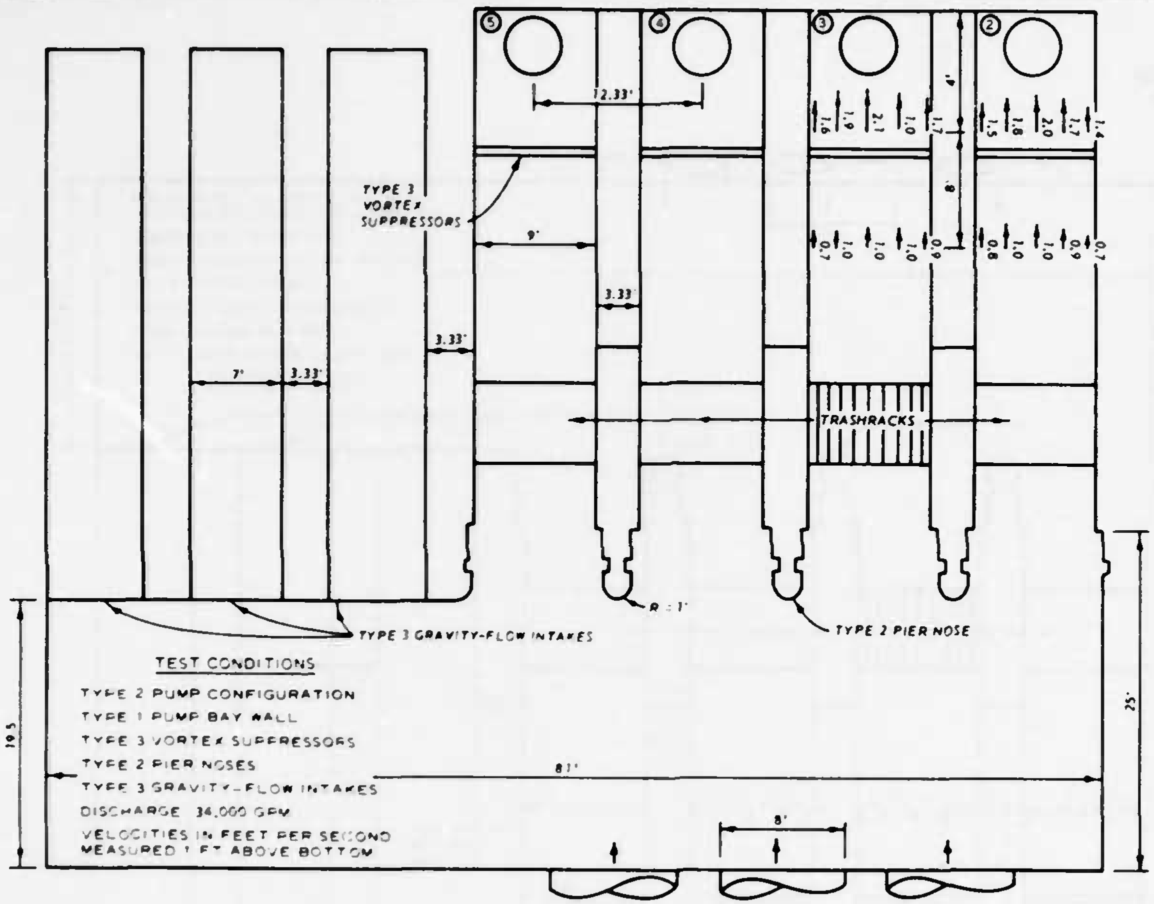
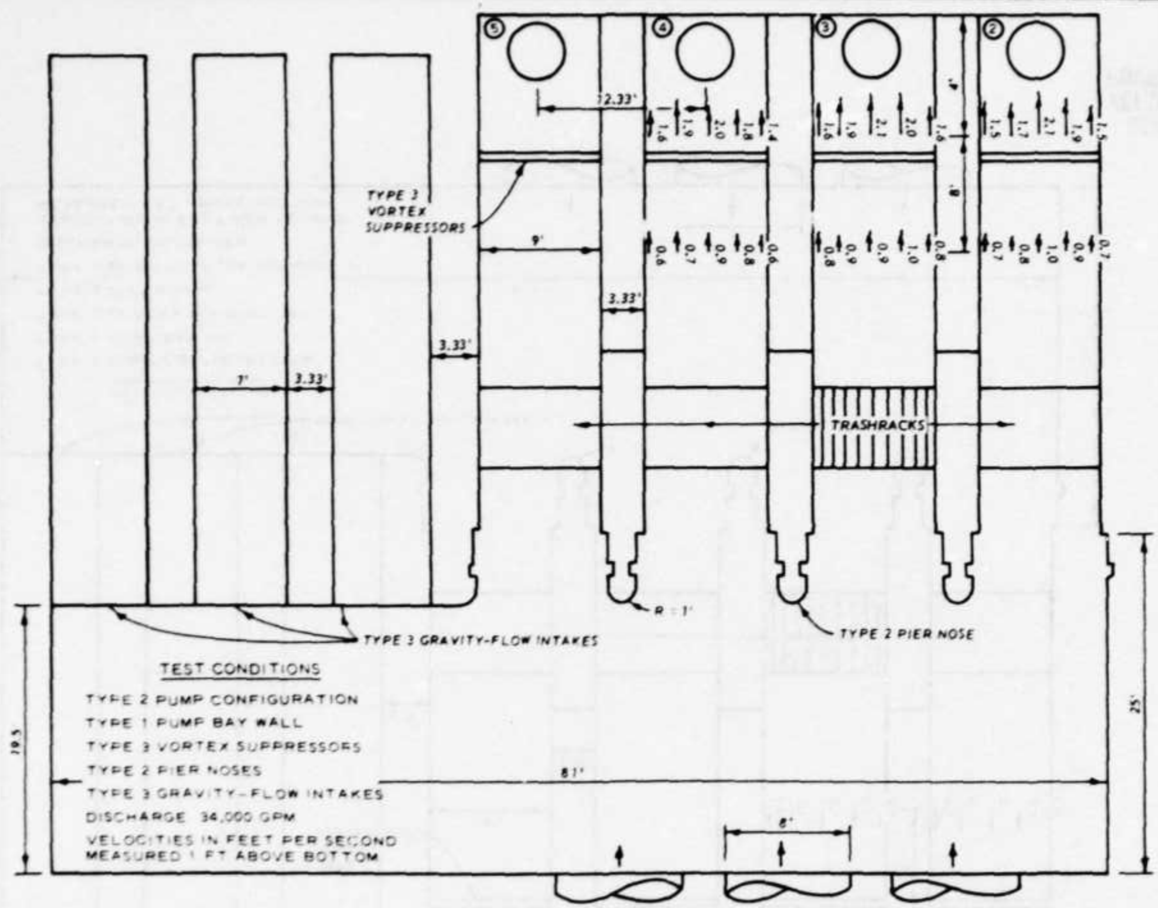

RECOMMENDED DESIGN
VELOCITY MEASUREMENTS
PUMP 5 OPERATING
SUMP EL 761
TEST CONDITIONS
TYPE 2 PUMP CONFIGURATION
TYPE 1 PUMP BAY WALL
TYPE 3 VORTEX SUPPRESSORS
TYPE 2 PIER NOSES
TYPE 3 GRAVITY-FLOW INTAKES
DISCHARGE 34,000 GPM
VELOCITIES IN FEET PER SECOND
MEASURED 1 FT ABOVE BOTTOM
36" PUMP
TRASHRACKS
TYPE 2 PIER NOSE
TYPE 3 VORTEX SUPPRESSORS
TYPE 3 GRAVITY-FLOW INTAKES
R 1'
12.33'
3.33'
81'
25'
19.5'
8'
7'
4'
1.5
1.7
2.1
1.8
0.7
0.9

PLATE 40

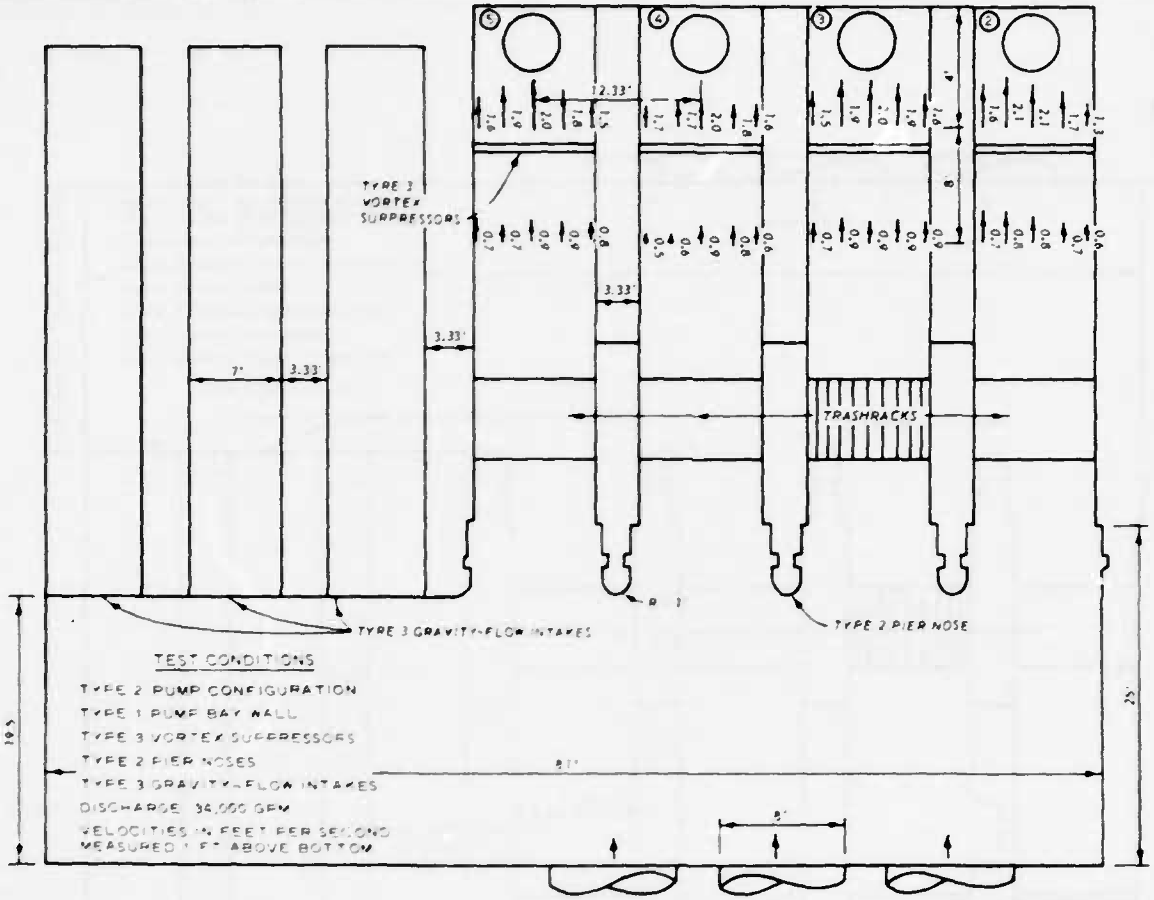


RECOMMENDED DESIGN
VELOCITY MEASUREMENTS
PUMPS 2 AND 3 OPERATING
SUMP EL 761



RECOMMENDED DESIGN
VELOCITY MEASUREMENTS
PUMPS 2, 3, AND 4 OPERATING
SUMP EL 761

PLATE 42



RECOMMENDED DESIGN
VELOCITY MEASUREMENTS
PUMPS 2, 3, 4, AND 5 OPERATING
SUMP EL 761

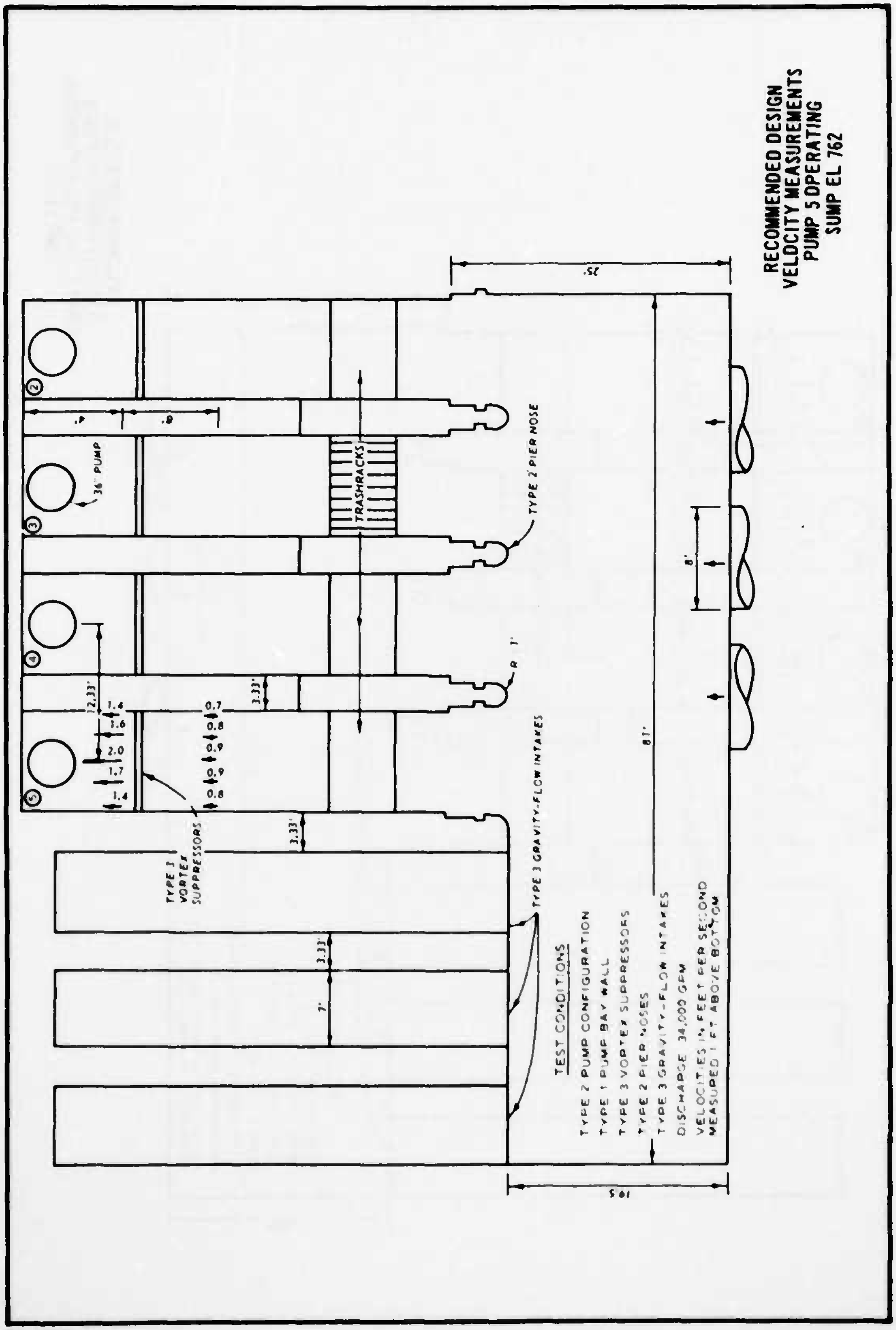
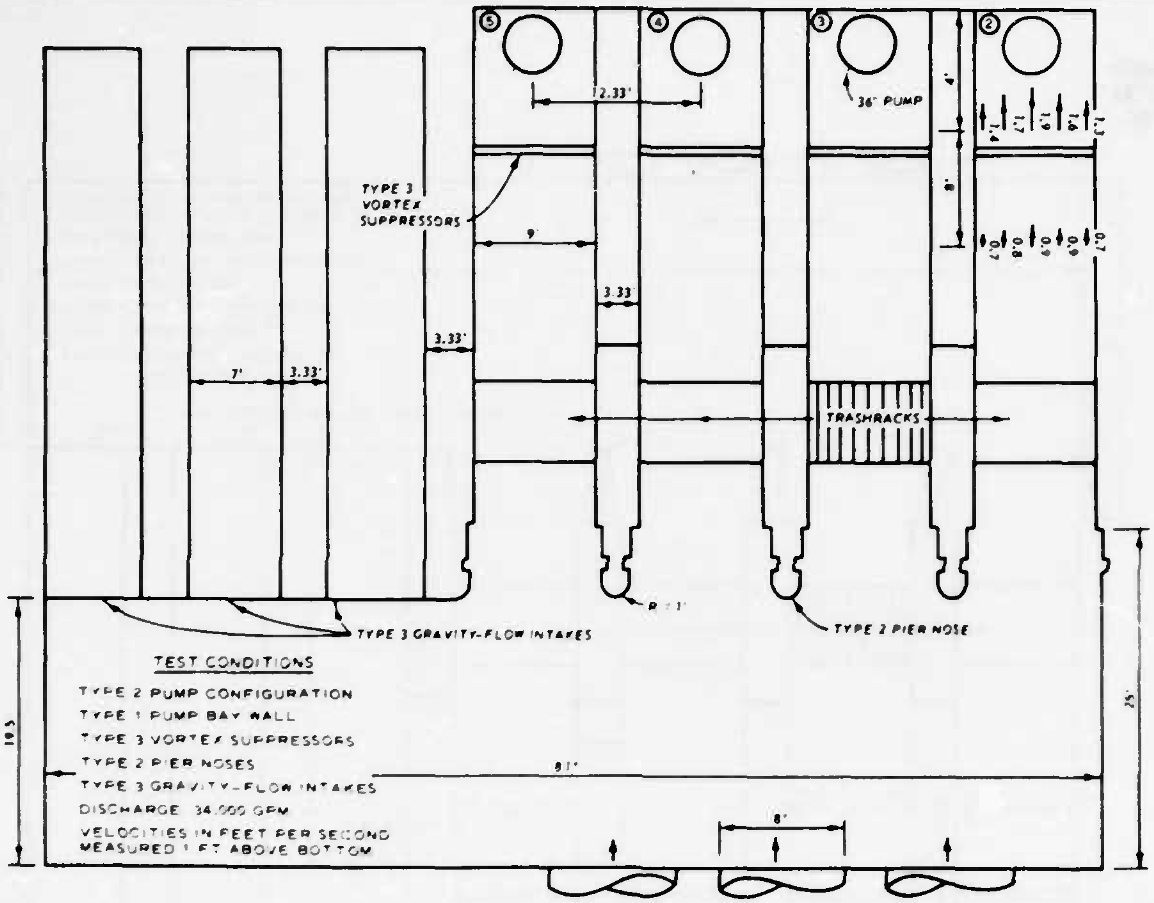
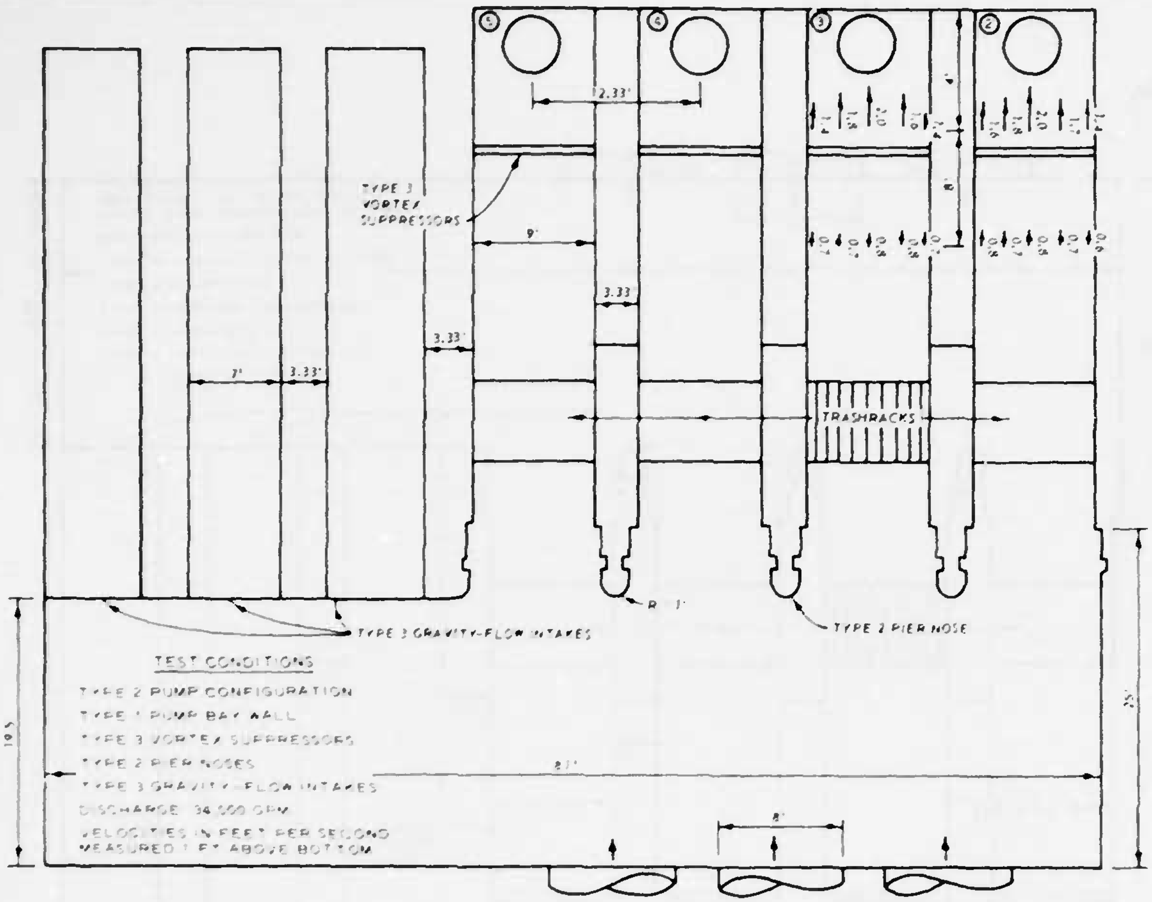

RECOMMENDED DESIGN
VELOCITY MEASUREMENTS
PUMP 5 OPERATING
SUMP EL 762
TEST CONDITIONS
TYPE 2 PUMP CONFIGURATION
TYPE 1 PUMP BAY WALL
TYPE 3 VORTEX SUPPRESSORS
TYPE 2 PIER NOSES
TYPE 3 GRAVITY-FLOW INTAKES
DISCHARGE 34,000 GPM
VELOCITIES IN FEET PER SECOND
MEASURED 1 FT ABOVE BOTTOM
TYPE 3 GRAVITY-FLOW INTAKES
TYPE 3 VORTEX SUPPRESSORS
TYPE 2 PIER NOSE
36" PUMP
TRASHRACKS
R 1'
81'
25'
19.5
8'
7'
3.33'
12.33'
1.4
1.6
2.0
1.7
1.4
0.7
0.8
0.9
0.9
0.9
0.8
2
3
4
5

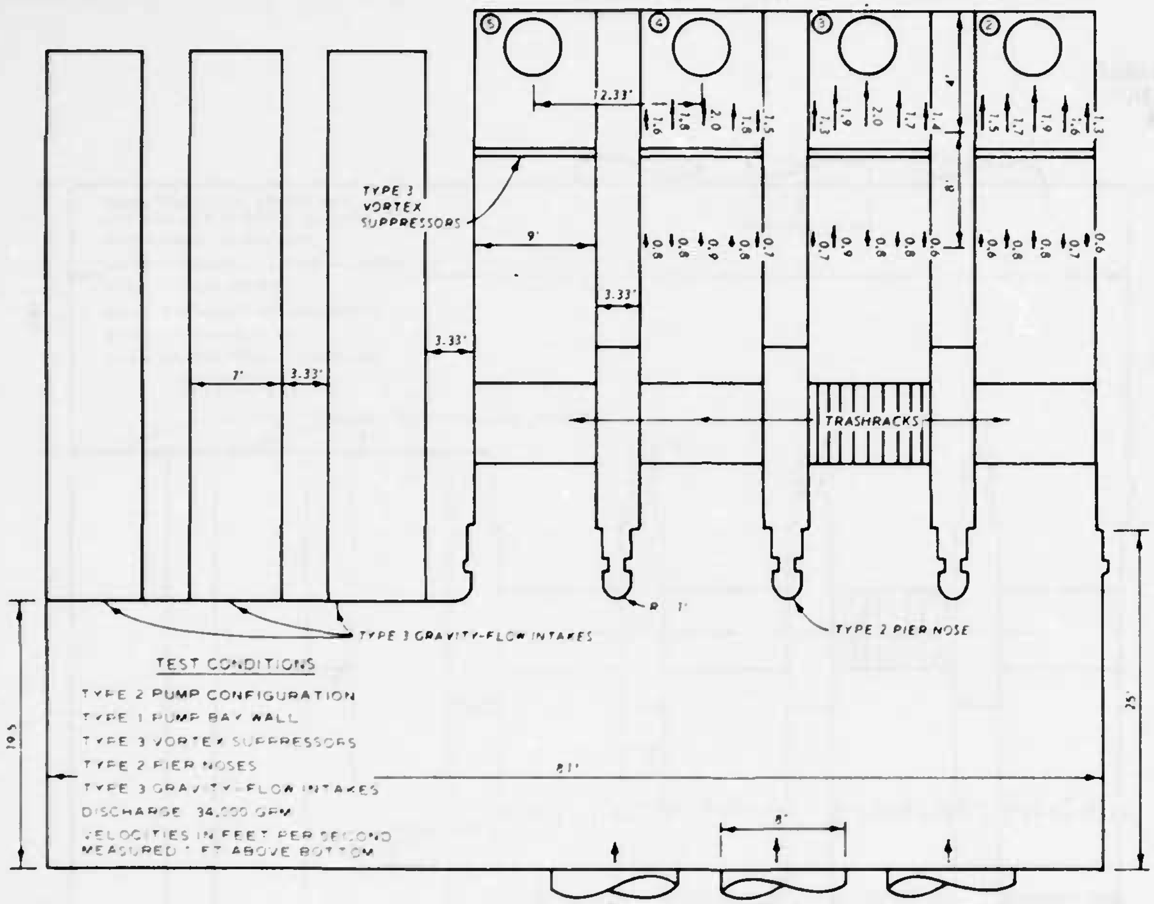
PLATE 44



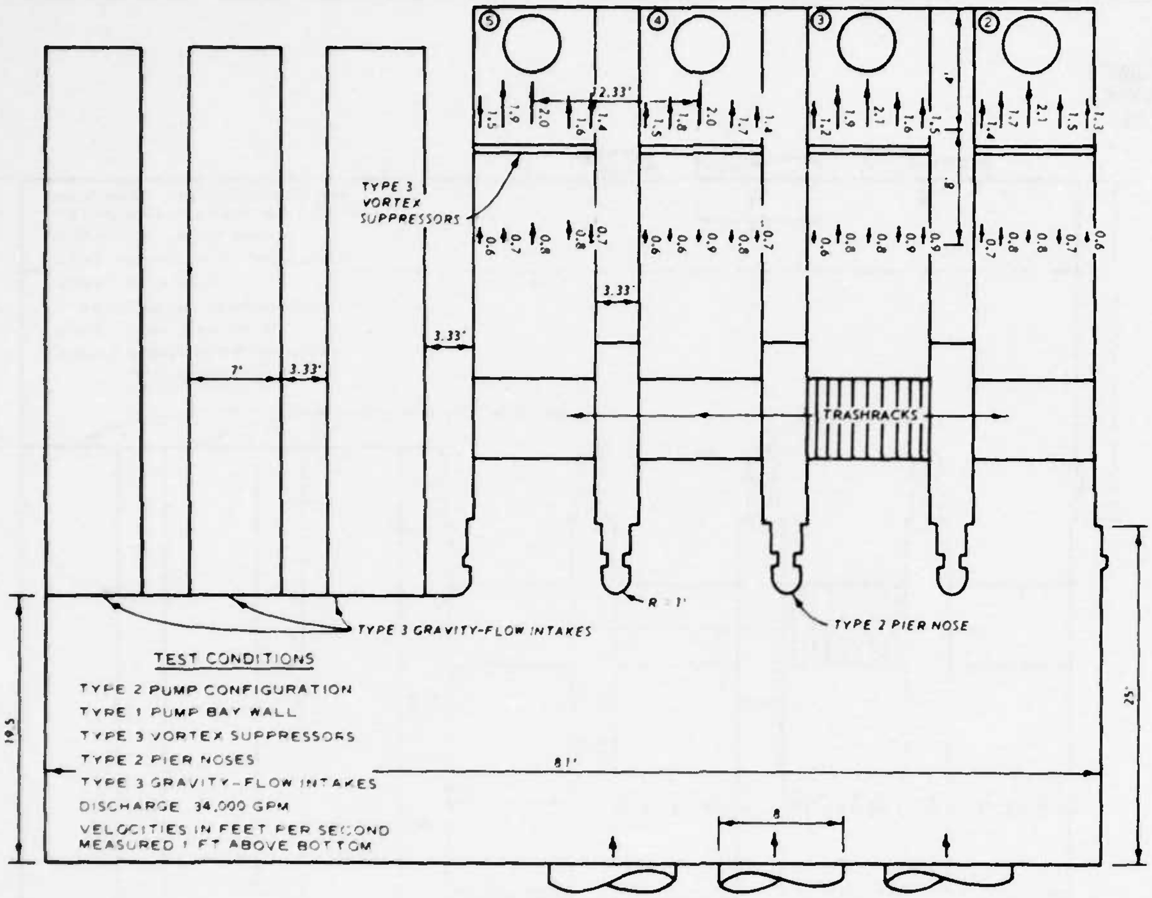
RECOMMENDED DESIGN
VELOCITY MEASUREMENTS
PUMP 2 OPERATING
SUMP EL 762



RECOMMENDED DESIGN
VELOCITY MEASUREMENTS
PUMPS 2 AND 3 OPERATING
SUMP EL 762



RECOMMENDED DESIGN
VELOCITY MEASUREMENTS
PUMPS 2, 3, AND 4 OPERATING
SUMP EL 762



RECOMMENDED DESIGN
VELOCITY MEASUREMENTS
PUMPS 2, 3, 4, AND 5 OPERATING
SUMP EL 762

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Fletcher, Bobby P

Indian Creek pumping station, Mankato, Minnesota; hydraulic model investigation / by Bobby P. Fletcher. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1978.

16, [27] p., 48 leaves of plates : ill. ; 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; H-78-8)

Prepared for U. S. Army Engineer District, St. Paul, St. Paul, Minnesota.

1. Entrances (Fluid flow). 2. Flow characteristics. 3. Hydraulic models. 4. Indian Creek Pumping Station. 5. Pumping stations. I. United States. Army. Corps of Engineers. St. Paul District. II. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Technical report ; H-78-8.

TA7.W34 no.H-78-8

END

9-78

DDC